TRANSACTIONS OF THE

American Foundrymen's Association

Proceedings of the

Thirty-First Annual Meeting

CHICAGO, ILLINOIS

June 7 to 9, 1927

VOLUME XXXV

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Summary of the Proceedings of the Thirty-First Annual Meeting

Chicago, Illinois, June 6 to 9, 1927

The thirtieth annual meeting of the American Foundrymen's Association, held at the Edgewater Beach Hotel, Chicago, June 6 to 9, 1927, was unique in the recent history of the Association as it was the first convention in twenty years held without an exhibit of foundry equipment and materials. Scheduled for a spring meeting by the Board of Directors in its desire to avoid conflicting dates of similar associations holding fall meetings and because of a desire to insure better weather conditions than usually prevail in the fall, the Board decided that following so close on the Detroit meeting of September, 1926, it would be inadvisable to hold an exhibit.

The meeting was an unqualified success in every way, with a registered attendance of 1,100 men and 254 ladies, technical sessions better attended than ever before, and an excellent program of plant visitation and entertainment provided by the local Chicago Committee. A large factor in the success of the meeting is attributed to the ideal location and facilities of the Edgewater Beach Hotel for such a meeting.

In addition to the general opening meeting, there were held twelve technical sessions, covering the following subjects:

Apprentice Training,
Sand Control,
Foundry Costs,
General Foundry Practice,
Foundry Pig Iron Qualities,
Non-Ferrous Foundry Practice,
Cast Iron Metallurgy,
Steel Founding,
Malleable Cast Iron,
Gray Iron Shop Problems.

Exchange papers from European associations were presented in behalf of the Institute of British Foundrymen, The Association Technique de Fonderie de Belgique, and the Association Technique de Fonderie de France.

An innovation was the presenting of brief committee reports at the opening business meeting, when twelve chairmen of committees reported. Some of these reports were amplified at later technical meetings. These reports covered the following activities:

Joint committee on pattern equipment standardization,
Investigation of the effect of sulphur and phosphorus in steel,
Corrosion of ferrous metals,
Foreign relations,
Apprentice training,
Joint committee on molding sand research,
Foundry costs,
Cast iron,
Heat treatment of ferrous metals,
Foundry refractories,
Placing of weights of castings on blueprints,
Steel castings specifications.

A demonstration of foundry sand testing equipment was conducted under the auspices of the Joint Committee on Molding Sand Research and apprentice contests in pattern making, steel casting molding and cast iron molding, were held. The apprentice contests were conducted in cooperation with local and district foundry organizations, the winning castings and patterns of the local groups being sent to Chicago for competition in a national contest. Organizations participating in the local contests were:

Harvey, Illinois, Apprentice Club,
General Electric Company, Erie, Pennsylvania,
National Metal Trades Association, Milwaukee, Branch,
New England Foundrymen's Association,
Pettibone-Mulliken Company, Chicago,
Quad City Foundrymen's Association.

The thirty-six technical papers presented at the various sessions were grouped as follows:

Apprentice	8
Costs	3
General foundry practice	4
Gray iron	9
Sand	2
Malleable iron	4
Steel	3
Non-ferrous founding	3

The non-ferrous round table meeting again proved very popular, being attended by about one hundred foundrymen. The feature meeting of all was the discussion session on qualities of foundry pig iron, although all sessions were exceptionally well attended and participation in the discussions very extensive and interesting.

Session No. 1—Opening Meeting—Annual Business Session.
Tuesday, June 7, 9:40 A. M.

President S. W. Utley presided at this meeting and in his opening remarks introduced Mr. W. J. Kelly, chairman of the convention board of the Chicago Association of Commerce, who gave an address of welcome to the visiting foundrymen, on behalf of the Association of Commerce. President Utley responded to the address of welcome, following which he discussed the purpose of the association.

The next order of business was the reading of brief reports of progress by the chairmen of A. F. A. committees.

D. M. Avey reported for the Joint Committee on Pattern Equipment Standardization.

R. A. Bull reported as the A. F. A. representative on the Joint Committee on Investigation of the Effects of Phosphorus and Sulphur in Steel.

The report of H. Y. Carson, as chairman of the Committee on Corrosion of Ferrous Metals, was read by President Utley.

H. Cole Estep reported for the Committee on International Relations. This report dealt largely with the formation of an

international committee to regulate the holding of international foundry congresses.

H. A. Frommelt read a report outlining the purposes and activities of the Committee on Apprentice Training.

B. D. Fuller, chairman of the Joint Committee on Molding Sand Research, gave a progress report of the activities of this committee.

A. E. Hageboeck reported for the Committee on Foundry Costs, outlining the policy to be pursued by this committee in its future activities.

J. L. Jones reported as chairman of the Committee on Cast Iron.

The report of A. W. Lorenz as chairman of the Committee on Heat Treatment of Ferrous Metals, was read by E. R. Young, a member of the committee.

C. N. Ring, chairman of the Committee on Refractories, reported on the work of the Joint Committee on Foundry Refractories.

A. B. Root, Jr., reported as the A. F. A. representative on the joint committee to consider the placing of weights of castings on blue prints.

A. H. Jameson, chairman of the Committee on Steel Castings, reported for his committee.

Following the report of the committee chairmen President Utley announced the appointment of the personnel of the Committee on Resolutions, and the judges of the apprentice molding and pattern contests.

Secretary Hoyt read the report of the nominating committee, nominating officers and directors. This report announced the nomination of the following:

For president, to serve one year—S. W. Utley.
For vice-president, to serve one year—S. T. Johnston.
For directors, to serve three years each:
E. H. Ballard, General Electric Co., West Lynn Massachusetts.
H. Y. Carson, American Cast Iron Pipe Co., Birmingham, Alabama.

W. D. Goldsmith, C. A. Goldsmith Co., Newark, New Jersey.
A. E. Hageboeck, Frank Foundries Corp., Moline, Illinois.
W. J. Nugent, Nugent Steel Castings Co., Chicago, Illinois.

A motion was approved declaring the election of these officers and directors as recommended by the nomination committee.

The meeting was then adjourned to reconvene at 4:00 p. m. on June 8.

Adjourned Business Meeting at Chicago Convention
4 P. M. Wednesday, June 8

Presiding—President S. W. Utley

President Utley called on Past President A. E. Howell, Chairman of the Committee on Resolutions, who read the resolutions which had been prepared by his committee. The committee's report is given below:

To the Members of the American Foundrymen's Association:

This, the Thirty-first Annual Convention of the American Foundrymen's Association, and the fourth to be held in Chicago, is different from all previous meetings of foundrymen—and yet alike—in that it has its own features of significance which differentiate it from all others. Beginning in 1896 as a purely technical organization, the exhibit feature of the A. F. A. evolved in a very natural way, until the vast aggregation of machines, appliances and supplies brought together at our meetings well nigh overshadowed the fundamental purposes. In the mind of the average foundryman they really did offer the "big attraction."

Realizing this, those chosen to guide our course have been always moved to go *with* and never *counter* to the current of general desire. Our exhibits grew to such proportions that only a few of the largest cities have adequate facilities for their housing, and the enormous expense made it proper to consult with utmost consideration the representatives of the exhibitors, who have the main financial burden. Changing from a fall meeting to a spring gathering, as was deemed expedient, would have brought two giant exhibits within one year, and in deference to our Exhibitors, our Advisory Board decided on this convention "sans" exhibit.

To this extent, this meeting was an experiment—and makes this thirty-first convention unique, returning as it does to the original idea.

The success of this meeting, exceeding by far our expectations in attendance, proves that thought and research, mutual interchange of ideas, plant visitation, and the companionship of those of kindred interests are magnets ever growing in strength. We shall have even greater relish, at our next meeting, for our exhibitors, whom we have known and loved and lost for so little while.

Thought rules the world.

Our physical scientists, their predecessors, and those we have with us have created our modern foundry world.

For all that, we have learned only partly how to use and apply the lessons we might learn. Let us honor and support them for the imagination they awaken, and the research which they offer us so freely.

The important thing is to get out of our minds the idea of monotony in life. There is no monotony unless we ourselves create it and believe in it.

Because of the unique success of this Convention, your committee offers the following:

Be It Resolved, That we are peculiarly indebted to the Authors of all the papers in the various sessions, and to those who have enlivened and heightened the interest by their timely discussions; To the Chairmen and members of all the committees, who have given so unstintedly of their time and radiant good nature; particularly to the Chicago Committees headed by Mr. William J. Nugent. To Col. T. S. Hammond, Mr. C. B. Carter, Mr. C. C. Kawin, Mr. John S. Sammons, Mr. David Evans, Mrs. Wm. J. Nugent, Mrs. C. E. Hoyt, Mrs. H. J. O'Neil, Mrs. C. C. Kawin, Mr. R. D. Phelps, Mr. G. A. Rolinson, Mr. C. P. Wright, and Mr. J. A. Byers.

To them and the members of their committees we feel unpayably indebted for courtesies and hospitalities that cannot be simulated.

Back of all these active committees has been the Chicago Association of Commerce, to whom we record our appreciation. We acknowledge it as a prime mover.

To the Management of the Edgewater Beach Hotel, whose constant concern for our pleasure and comfort we gratefully acknowledge. The Edgewater Beach is ideally beautiful and fitted for our meeting.

We cannot too fully express our esteem for our President, Stuart Wells Utley, who from his inauguration has worked with no thought of self, but with the single purpose of the greatest good for the organization.

With him we wish to include Mrs. Utley, by whose help he has been enabled not only to head the material purposes of our meeting, but to have added to them the social charm which ladies only can give.

To our Vice-President, S. T. Johnston, we also wish to record our appreciation, and to our "only one of his kind," C. E. Hoyt, Executive Secretary, and his staff. To R. E. Kennedy, Technical Secretary, who has been indefatigable in securing and welding together what will be our next Volume of Transactions. It is almost trite to repeat our appreciation of each of them, and for our Board of Directors, individually and collectively.

To their marital partners, who have assisted in making this meeting so much like a great house party, we wish to add our profound respect. To science and industry has been added the refinements due to the notably increased attendance of the wives of our members.

Nothing has been omitted to make this thirty-first Convention most successful. If there was any slight hitch, not known to us, in the plans so elaborately laid and so generously carried out, if remembered at all, it will be but as a thing happening by chance.

As we take leave of Chicago, and of our old friends here, and new ones made, her innumerable foundry industries in which we have been made so welcome, we would say—as Cleopatra to Cæsar—

"Your scutcheons and your signs of conquest shall hang in what place you please."

Respectfully submitted,

ALFRED E. HOWELL,
G. H. CLAMER,
DAN M. AVEY.

On motion, the report of the resolution committee was accepted as read.

Benjamin D. Fuller, Chairman of the Committee of Judges of the Apprentice Molding Contest, reported the winners in the Steel and Iron Molding Contests. The report of the committee read as follows:

To the Members of the American Foundrymen's Association:

Four steel and eighteen gray iron castings were submitted this year in the annual apprenticeship molding contest conducted by the Apprenticeship Training Committee of the American Foundrymen's Association. Local contests first were held in five foundry centers to determine which castings should be sent to convention headquarters for final inspection. Each casting bore a tag with an identifying number and the time required to make the mold for the casting. The names of the contestants remained in the hands of the secretary of the committee and were not given to the judges until after they had made their awards.

Primarily the contest was designed to indicate the molding ability of the boys in green sand work and for that reason the two best gray iron castings were not considered, because apparently the molds had been skin dried. Also the molding time on both was excessive. On one it was given as five hours. The remainder of the gray iron castings almost without exception reflected great credit on the boys who made them and the selection of the first, second and third hinged on a few minor details. Minor points of difference were given consideration in judging the steel castings and the final decision principally was influenced by the manner in which the castings were gated.

By a curious coincidence the three best iron castings came from the General Electric Company. This year they came from the Lynn, Massachusetts, works, while last year the three best castings came from the Erie, Pennsylvania, works of the company. In order of merit the castings were made by H. E. Stromberg, Y. Sawtelle and W. Urquhart. In the same order of merit the first steel casting was made by Carl H. Oleson, Pettibone-Mulliken Company, Chicago; the second by Andrew Bottoni, Falk

Corporation, Milwaukee, and the third by Joseph Buneta, also at the plant of the Falk Corporation at Milwaukee.

Respectfully submitted,

B. D. FULLER, *Chairman,*
PAT DWYER,
EUGENE W. SMITH.

In the absence of W. F. Grill, Chairman of the Committee of Judges of the Pattern Making Apprentice Contest, the report of this committee was read by Secretary Hoyt.

Report of Apprentice Pattern Making Contest:

We, the undersigned, appointed judges of the Apprentice Pattern Making Contest, have decided on the following awards:

Siegfried V. Hanson, Pettibone-Mulliken Company, Chicago, awarded first prize, due to completeness, workmanship, and accuracy. Core prints better proportioned and comply with our standards more closely.

Joseph Asp, Pettibone-Mulliken Company, awarded second prize, due to completeness, workmanship and accuracy.

Lester G. Furber, Brown and Sharpe Manufacturing Company, Providence, Rhode Island, awarded third prize, due to workmanship, but this pattern only contained a half core box. It had no identification marks of any kind and the drag core print is out of proportion and unnecessarily large.

There are others that had considerably less hours but who sacrificed accuracy and neatness for time. Some of them worked very closely to our standards and our color scheme, and they all deserve credit for their splendid work.

Respectfully submitted,

WM. F. GRILL, *Chairman,*
W. C. EWALT,
J. C. PALMER,

Committee of Judges for Apprentice Pattern Making Contest.

These two committee reports were approved as read and referred to the A. F. A. Board of Directors.

The following resolution, which had been adopted at a members' session, was accepted as read and was referred to the Board of Directors for action:

"Be It Resolved, That it is the consensus of this assembly that a cooperative study of the effects of varying blast furnace operations on the character of the pig iron made under changing blast furnace conditions, and on the castings made therefrom, be conducted under the supervision of the United States Department of Commerce, with an advisory committee consisting of representatives of the national technical associations, such as the A. F. A., American Pig Iron Association, A. I. M. and M. E., and the A. S. T. M."

Following an announcement by Secretary Hoyt, giving convention attendance figures, the meeting was adjourned.

Session No. 2—Apprentice Training.

Tuesday, June 7, 11:00 A. M.

Chairman, C. J. Freund, The Falk Corporation, Milwaukee, Wis.

In opening the meeting the chairman introduced F. A. Lorenz, works manager of the Indiana Harbor plant of the American Steel Foundries, who discussed the apprenticeship situation in his district. Following this talk the following papers were presented:

METAL TRADES ASSOCIATION LAUNCHES A NEW APPRENTICE TRAINING CAMPAIGN IN MILWAUKEE, by C. J. Freund, apprentice supervisor, The Falk Corporation, Milwaukee, Wis.

A REAL TRAINING PROGRAM DESTROYS PREJUDICE, by G. Hayes, director of vocational education, Thornton Township high school, Harvey, Ill.

MAKING APPRENTICESHIP PAY DIVIDENDS, by W. B. Perry, Industrial Works, Bay City, Mich.

COOPERATION FIRST ESSENTIAL TOWARDS SUCCESS IN APPRENTICESHIP, by H. Jansen, executive secretary of the Tri-City Manufacturers' Association, Moline, Ill.

CAREFUL SELECTION AND SUPERVISION ARE IMPORTANT IN REDUCING APPRENTICE TURNOVER, by W. Watson, works manager, Allis-Chalmers Manufacturing Company, Milwaukee, Wis. This paper in the absence of the author was read by L. W. Wiggins, employment manager of the Allis-Chalmers Company.

A PUBLICITY PROGRAM, JUSTIFIED BY CORRECT METHODS OF APPRENTICESHIP, TO ATTRACT YOUNG MEN, by H. J. Roesch, director of apprenticeship, Chicago branch, National Metal Trades Association.

TRAINING APPRENTICES, by A. W. Gregg, general superintendent, The Bucyrus Company, Milwaukee, Wis.

UPGRADING FOUNDRY APPRENTICES, by C. H. Ross, The Union Malleable Iron Company, East Moline, Ill. This paper in the absence of the author was read by Mr. Brown, foundry superintendent, of the Union Malleable Iron Company.

APPRENTICE TRAINING IN THE PITTSBURGH DISTRICT, by Dr. C. B. Connelley, Carnegie Institute of Technology, Pittsburgh, Pa.

Session No. 3—General Foundry Practice.

Tuesday, June 7, 11:00 A. M.

Chairman, J. W. Bolton, The Lunkenheimer Company, Cincinnati, Ohio.

Papers read and discussed were as follows:

CORE OIL SPECIFICATIONS, by V. A. Crosby, metallurgist, Studebaker Corporation, South Bend, Ind.

TESTS TO ESTABLISH THE FLUIDITY OF CAST IRON, by C. Curry, Ardennes, France. This paper, the exchange contribution of the Association Technique de Fonderie de France, in the absence of its author was read by J. T. MacKenzie of the American Cast Iron Pipe Company.

FOUNDRY BLACKINGS, by A. N. Ogden and D. G. Anderson, The Western Electric Company, Chicago, Ill.

ANALYSIS OF FOUR HUNDRED TONS OF DEFECTIVE CASTINGS, by J. M. Haley, Crompton and Knowles Loom Works, Worcester, Mass. This paper was read in abstract by R. E. Kennedy.

Session No. 4—Foundry Costs.

Tuesday, June 7, 2:30 P. M.

Chairman, A. E. Hageboeck, Frank Foundries Corporation, Moline, Ill.

In opening this meeting Chairman Hageboeck discussed the findings of the A. F. A. cost committee. No printed papers were read, but the following informal talks were given:

A UNIFORM COST SYSTEM FOR A LOCAL GROUP, by J. L. Carter, The Barlow Foundry, Inc., Newark, N. J.

SEVEN YEARS OF FOUNDRY COST ACCOUNTING IN THE CINCINNATI DISTRICT, by Albert Wessling, Cincinnati, Ohio.

GROUP FOUNDRY COSTS, by D. McDaniel, Hamilton Foundry and Machine Company, Hamilton, Ohio.

The discussion resolved itself largely into a discussion of how a local group of foundrymen could organize to foster the use of uniform methods of determining costs.

Session No. 5—Qualities of Pig Iron for Casting Purposes.

Tuesday, June 7, 2:30 P. M.

Chairman, R. H. Sweester, The American Rolling Mill Company, Columbus, Ohio.

This session was for the purpose of informally airing views on the varying qualities of pig iron for foundry purposes. Two papers were read as printed, the other talks being informal presentations of views by representatives of blast furnace organizations and users of pig iron. The two printed papers read were:

THE EVALUATION OF FOUNDRY PIG IRON, by Dr. Richard Moldenke, Watchung, N. J.

AN EXPRESSION OF VIEWS ON THE USE OF SCRAP IRON IN THE BLAST FURNACE, by David McLain, Milwaukee, Wis.

The following motion was adopted for approval by the A. F. A. board of directors:

"Be It Resolved, that it is the consensus of this assembly that a cooperative study of the effects of varying blast furnace operations on the character of the pig iron made under changing blast furnace conditions and on the castings made therefrom be conducted under the supervision of the Department of Commerce, with an advisory committee consisting of representatives of the national technical associations, such as the American Foundrymen's Association, the American Institute of Mining and Metallurgical Engineers, The American Pig Iron Association and the American Society for Testing Metals."

Session No. 6—Foundry Sand Control.
Wednesday, June 8, 10:00 A. M.

Chairman, Benjamin D. Fuller, past president of the A. F. A. Papers and reports read and discussed were as follows:

ROUTINE SAND CONTROL IN THE PIPE FOUNDRY, by Max Kuniansky, Lynchburg Foundry Company, Lynchburg, Va.

REPORT OF SUB-COMMITTEE ON GRADING FOUNDRY SANDS, read by Chairman B. D. Fuller.

REPORT OF SUB-COMMITTEE ON TESTING FOUNDRY SANDS, read by Dr. H. Ries, chairman of the sub-committee.

REPORT OF SUB-COMMITTEE ON CONSERVATION AND RECLAMATION OF FOUNDRY SAND, read by R. F. Harrington, chairman of the sub-committee.

EFFECTS OF MOISTURE ABSORPTION ON THE PROPERTIES OF DRY SAND CORES, by H. L. Campbell, University of Michigan, Ann Arbor, Mich.

Session No. 7—Round Table Discussion on Brass Founding
Wednesday, June 8, 12:15 P. M.

Chairman, N. K. B. Patch.

This session was held for an informal discussion of practical shop topics and no set papers were read. As no reporter was present no record of discussion was kept. During the luncheon time, which preceded the discussion period, questions for discussion were proposed by those at each table. These questions

were then handed to the chairman, who later called for discussion on them.

Session No. 8—Cast Iron Metallurgy

Wednesday, June 8, 1:30 P. M.

Chairman, R. F. Harrington, Hunt-Spiller Manufacturing Corporation, Boston, Mass.

The following papers were read and discussed:

SOME GRAPHITE FORMATIONS IN GRAY CAST IRON, by J. W. Bolton, The Lunkenheimer Company, Cincinnati, Ohio.

FATIGUE TESTS OF CAST IRON, by H. F. Moore and S. W. Lyon, University of Illinois, Urbana, Ill.

THE GROWTH OF CAST IRON, by Dr. J. H. Andrew, Royal Technical College, Glasgow, Scotland. This, the annual exchange paper of the institute of British Foundrymen, in the absence of the author was read by H. Bornstein of Deere and Company, Moline, Ill.

THE EFFECT OF CHROMIUM AND NICKEL IN CAST IRON, by R. S. Poister, Electro-Metallurgical Sales Corporation, New York, N. Y.

Session No. 9—Malleable Foundry Sand Control.

Wednesday, June 8, 1:30 P. M.

Chairman, L. C. Wilson, The Federal Malleable Company, West Allis, Wisconsin.

At this session organized to discuss sand control in the malleable foundry, only one paper was prepared. This paper was:

SYNTHETIC MOLDING SANDS IN THE MALLEABLE SHOP, by F. C. Scheiber, General Electric Company, Erie, Pa.

H. B. Hanley, The Whitehead Brothers Company of Rochester, N. Y., and H. W. Dietert, the U. S. Radiator Corporation of Detroit, were discussion leaders.

Session No. 10—Steel Founding.

Wednesday, June 8, 1:30 P. M.

Chairman, R. A. Bull, past president A. F. A.

The following papers and reports were presented and discussed:

A NEW TYPE OF MOLD DRYING OVEN, by J. M. Sampson and G. H. Wright, General Electric Company, Schenectady, New York. This paper was read by J. M. Sampson.

CHARACTERISTICS OF SOME STEEL MOLDING AND CORE SAND MATERIALS, by E. R. Young, The Detroit Steel Casting Company, Detroit, Mich.

REPORT OF A. F. A. COMMITTEE ON STEEL CASTINGS, presented by A. H. Jameson, chairman of the committee.

REPORT OF A. F. A. REPRESENTATIVES ON JOINT COMMITTEE FOR THE INVESTIGATION OF THE EFFECTS OF PHOSPHORUS AND SULPHUR IN STEEL, presented by R. A. Bull, A. F. A. representative on committee.

REPORT OF COMMITTEE ON HEAT TREATMENT OF FERROUS METALS, presented by A. W. Lorenz, chairman of committee

FATIGUE TESTS OF CAST STEEL, by H. F. Moore, University of Illinois, Urbana, Ill.

Following the discussion of the report of the Committee on Steel Castings, in which the proposed A. S. T. M. Specifications for Carbon Steel Castings for Valves, Flanges and Fittings for High Temperature Service were discussed, the following resolution was passed:

RESOLVED; that it is the consensus of opinion of the steel foundrymen attending the 31st annual convention of the American Foundrymen's Association in regular meeting assembled that it would be unfair and unscientific for the American Society for Testing Materials to discriminate in eliminating any steel making process, or to establish mandatory limits for carbon, manganese, or silicon while specifying physical properties, in any tentative or standard specifications for steel castings.

The resolution was referred to the A. F. A. Board of Directors.

Session No. 11—Gray Iron Shop Problems

Thursday, June 9, 10:00 A. M.

Chairman, L. L. Anthes, Past President A. F. A.

The following papers were read and discussed:

CAST CHAPLETS AND TINNED AND UNTINNED CORE IRONS, by Jacques Varlet, Sclession, Belgium. This, the exchange paper of the Association Technique de Fonderie de Belgique, in the absence of the author, was read by R. E. Kennedy.

CORRECTION OF CUPOLA OPERATION BY MEANS OF CUPOLA TEMPERATURE RECORDERS, by H. W. Dietert, The U. S. Radiator Company, Detroit, Mich.

A STUDY OF CUPOLA LINING REFRACTORIES, by G. S. Schaller, The University of Washington, Seattle, Wash.

REPORT OF JOINT COMMITTEE ON PATTERN EQUIPMENT STANDARDIZATION, read by D. M. Avey, chairman of the joint committee.

Session No. 12—Non-Ferrous Founding

Thursday, June 9, 10:00 A. M.

Chairman, N. K. B. Patch, Lumen Bearing Company, Buffalo, N. Y.

Papers read and discussed were as follows:

REDUCTION OF MOLDING LOSSES, by R. A. Greene, The Ohio Brass Company, Mansfield, Ohio.

IMPROVEMENT OF ALUMINUM BRONZE AS AN ENGINEERING MATERIAL, by Dr. R. C. Reader, Birmingham, Eng.

SYMPOSIUM ON GATING BRASS AND BRONZE CASTINGS, R. L. Binney, Toledo, Ohio.

D. E. Broggi, Neptune Meter Company, Long Island City, N. Y.

C. V. Nass, Ohio Brass Company, Mansfield, Ohio.

W. F. Herst, Wolverine Brass Works, Grand Rapids, Mich.

E. F. Hess, The Ohio Injector Company, Wadsworth, Ohio.

R. R. Clarke, General Electric Company, Erie, Pa.

Session No. 13—Malleable Foundry Problems

Thursday, June 9, 10:00 A. M.

Chairman, L. C. Wilson, Federal Malleable Company, West Allis, Wis.

Papers read and discussed were as follows:

VARIATIONS IN PIG IRON QUALITIES, by Professor R. S. McCaffery, University of Wisconsin, Madison, Wis.

MALLEABLE FOUNDRY REFRACTORIES, J. R. Allan, International Harvester Company, Chicago, Ill.

PICKLING SOLUTIONS, by F. L. Wolf, Ohio Brass Company, Mansfield, Ohio.

Proceedings Annual Banquet

Wednesday, June 8, 1927, Edgewater Beach Hotel

Chicago

The annual banquet of the American Foundrymen's Association was held at the Edgewater Beach Hotel Wednesday evening, June 8, with President S. W. Utley presiding.

President Utley read a telegram from Paul Ropsey, on behalf of the European Foundrymen's Associations, expressing their feeling of good will and wishing prosperity to the American Foundrymen's Association.

S. C. Vessy, chairman of the mileage contest committee, reported the result of the contest, stating that the New England Foundrymen's Association, with an attendance of 12, and a traveling mileage of 12,228 miles, won the award for local associations. The award, a silver mounted gavel, was received by R. F. Harrington, past president of the N. E. F. A.

President Utley then gave an address on the foundry industry which is printed in full below:

PRESIDENT S. W. UTLEY: Ever since it was decided to hold this meeting without an exhibit I have felt that I noticed a feeling of sorrow whenever our genial secretary spoke to me about the prospects for the meeting. I don't mean to say by this that he has not been optimistic, because he has been more optimistic than anyone else, but with all his optimism there seemed to be a doleful vein. He said to me a good many times, "You know this convention is going to be quite different from the usual one. We are not going to have the bang and the noise and the bustle of the exhibit and I am afraid that we are going to miss that din."

When I saw him in Philadelphia some three weeks ago, it seemed to me that he was much more cheerful. After we had been together a day and he had gotten up his nerve, he finally said to me, "Wells, my misgivings, I think, are all a thing of the

past. The committee has decided that in view of the fact that we are not going to have all that noise and bustle and turmoil, they will ask you to make a speech." So if when I am through, you are unable to find any thoughts in my scattered remarks, just remember that I am merely pinch-hitting for an air compressor and my only function is to make a noise.

The other night, when I started to think about this subject which is so near to all of us and yet about which I sometimes think we know so little, I began to wonder just how old the foundry industry was in the history of the world. So I dug out the Encyclopedia Britannica and tried to follow back the trail of foundries. I found that for the first few generations it was a broad and well developed boulevard, which led us back through the Middle Ages, back through the Roman Empire, back through the period of Grecian civilization, and then narrowing down somewhat, led us into the days of Egyptian civilization, past the days of the Pharaohs, past the days of the pyramids, past the point where man first learned to weave textiles and make garments for himself, past the point where he first learned to make pottery. Then a straggling and difficult trail to follow, it led on to the point where the frontiers of human knowledge draw the veil of oblivion across the path of history and where man reads the story of prehistoric times only in the faces of the stones, and where he counts time, not in years or centuries, but only in ages. For the encyclopedia tells us that there is undisputed evidence that men first made molds and poured molten metal into them not later than the middle of the Neolithic Age, the period of the Smooth Stone Era. Six thousand, seven thousand, maybe eight thousand years ago man first made molds and started our industry. This industry stands today older than science; older, perhaps, than art; older than any system of philosophy we have; older than any religion that remains on the earth today.

In these days, when so many people who class themselves as intellectuals chide us with the fact that ours is a materialistic age, and seem to infer that we are traveling on a lower plane than we might if we thought less of material things and more of something else, the details of which, however, they fail to specify, have you ever stopped to wonder what is the purpose of our

civilization? For what, after all, are we all living? Surely it can't be that the race today lives simply to make molds or make buildings or make automobiles or anything else.

Is the object of our civilization to develop a great brain so that some man may think great thoughts? If it is, we have no evidence that the best brain of this generation surpasses in any way the best brain of 5,000 years ago, and we know that no philosophy has been given us of recent generations anywhere nearly so significant as that of the ancients.

Is it that we bring forth great artists to make beautiful statues or beautiful buildings? No buildings have been built in the Twentieth Century so beautiful as those of the ancient Greeks, nor probably of so enduring a character. No statues have been chiseled that even rival the work of their great artists.

Is the object of our civilization to bring forth some new idea of the relationship of man to his God? There has not been a single new contribution to religion in 2,000 years.

If we are to measure the progress of the human race by its intellectual development, it seems to me that we must come to the conclusion that the race reached its apex at about the time that we began to write our history, and that since then, practically speaking, there has been no development.

But, my friends, the civilization of Greece, with all its beauty, with all its art; the civilization of Rome, with all the great things that it left to us, were builded upon the foundation of one of the most abject systems of slavery that the world has ever known. The great mass of men were born, lived and died that a few might become immortal. Even today I think you will find that it is only in those places where industrial development has reached a high type that human life is considered of relatively more value than that of the animals. It is only when man seizes the forces of nature, when he harnesses them to a machine, so that that machine may do the work of his hands, that life itself becomes of any real value to society.

Look at China, where the penalty for the theft of a chicken is the execution of the thief. Look at India, where but recently human sacrifice has ceased to be. Look at Africa, where if a man on the trail in the caravan falls sick by the wayside, his

companions leave him to die without regret, to die and become the prey of the animals of the jungle. If you go throughout the world you can gauge the value of human life by the stage which the country has reached in industrial development.

Measurement of Progress Is the Betterment of All the People

I take it, then, that the measure of human progress, the measure by which we have to gauge the difference between the centuries just passed and those of ancient times, is not the status of the isolated individual, but rather the amount by which the condition of the great multitude has been raised by the increase in prosperity, leisure and opportunity for happiness; by the increased facility the average man has for improving the position of those whom he loves and who are dependent upon him. If this be the measure of progress, then industry, of which we are all a part, has had more to do with progress than any other one factor.

The Place of the Foundry

If this be true, what is the position of our own calling in this picture?

When you make a mold, pour some metal into it, take it down to the cleaning room and turn out a finished casting, you have made something that is absolutely *new*. The pattern may be old, the design may be ancient, but the thing you have produced never existed before. When the whistles of our foundries blew tonight, the world was richer than it was when the sun rose this morning by the product that we had turned forth. The foundry is not rehashing that which has been. It is creating something that is new; something to help the future of the race.

Notwithstanding that we are so old, we are coming to realize that our industry is so complicated that we know little or nothing about it. Any man who handles molten metal is daily confronted with problems which tax his utmost ingenuity. A few years ago we used to gauge pig iron by its fracture. Then we called in the chemist, only to find that he did not tell us the whole story. Spurred on by the demands of society for a better and better product, we turned to the microscope and to instruments of which our fathers knew nothing. With them we began to explore our

sands, our facings, our metals, only to find undreamed of mysteries challenging our intellect and demanding our best effort for their solution.

This Association was born thirty-two years ago in Philadelphia. I think it is perhaps significant that being one of the oldest industries in the world, this was one of the first great national associations organized in this country, and doubly significant that the ten years which followed and which marked the organization of most of our great national associations also marked the close of the century brought in by the French Revolution, whose dominant philosophy was the absolute supremacy of the individual. And I suspect we shall some day see that this period spelled an epoch in the story of mankind, marking as it did the willingness on the part of the individual to sacrifice something of his own freedom in order that he might co-operate with others.

This Association was born because men realized that it was much better that men in an industry should help each other, rather than fight each other. It was born because men began to see that no matter how much an individual thought he knew about his own business, there was always someone who could tell him something which would be of advantage to him. It was born because the industry realized that with the tremendous problems before it, the only way this could possibly be solved was by massing the best ability and the best brains for the attack. For after everything else has been said, the real object of this organization is simply to find the truth.

My friends, it is a wonderful thing to be connected with industry in this great industrial world, where each man is honestly striving to make money for himself and those dependent upon him, conscious, however, that the only way in which he can attain this goal is by rendering to society a service by which he gives her more than he gets back. It is a wonderful thing to be connected with an industry which is so old that we cannot find where it began, and yet which is so young, so inexperienced, so unknown, that it challenges the best of our executive ability, the best of our engineering skill, the best of our scientific research. It is a significant thing to be connected with a great organization

of this kind, where men are meeting together, each one to help himself by helping his competitor, where men are willing to devote their time, their work and their money in an effort to make of their industry an instrument which shall be of greater worth to the world and produce more of happiness for the children of God.

The next order of business was the presentation of the Joseph S. Seaman gold medal to Major R. A. Bull.

PRESIDENT S. W. UTLEY: Many of you know that through the generosity of four of the charter members of this association, permanent funds have been placed at its disposal, whose income is to be used in the judgment of the Board of Awards to present some form of recognition for work done for the foundry industry. The handling of those funds is under a separate board, composed of the last seven presidents. It would, I think, be quite useless for me tonight to attempt in any way to introduce or describe or praise the man who is Chairman of this Board, who was your President last year, and who has served you with such distinction for so many years before. It would obviously be quite improper for me to say anything about the subject with which he is to deal and so I am just going to introduce as Chairman of the Board of Awards, Past President A. B. Root, Jr.

A. B. ROOT, JR.: Mr. President, officers, members and friends of the American Foundrymen's Association and Major Bull:

The award selected by the Board for presentation this year was made possible through the generosity of Joseph S. Seaman, past president, honorary member and devoted friend of the American Foundrymen's Association.

To all but a few, if any, of those now actively engaged in the affairs of the Association, "Daddy" Seaman and the part he played in its affairs are known simply as a story passed on by those loyal and self-sacrificing individuals who labored diligently that the foundations for an association of which they had a vision might be securely laid.

It is one of these early members that our Association this night is to honor.

It gives me great pleasure to announce the decision of the Board in the selection of Major Robert Alexander Bull as the recipient in 1927 of the Joseph S. Seaman Medal of the American Foundrymen's Association.

Major Bull was born in New Albany, Indiana, in June, 1874. He received his education at Butler College from which he was graduated in 1897 with the degree of Bachelor of Arts. In 1914, seventeen years later, he received his Master of Arts degree from St. Louis University. This interval between degrees is in itself significant of the trend of his mind toward research and the problems requiring intensive mental application.

For the first few years he was an inspector with Robert Hunt & Co., industrial engineers, and then for a period of twenty-five years was associated with a number of the leading iron and steel companies in the country in positions of constantly increasing responsibilities.

He left the Duquesne Steel Company, where he was vice-president and general manager, to serve his government in France during the war as major in the ordnance department, where his wide and comprehensive knowledge of the steel casting business was of inestimable value.

When in 1921 a group of six electric steel foundries decided to collaborate in the solution of problems incident to their branch of the industry, Major Bull was tendered and accepted the position of research director of the newly formed Electric Steel Founders' Research Group.

By his education, by his valued experience with many steel foundries and by his natural resourcefulness, he has become a leading figure among steel foundries in the development of a better product and the solution of problems arising through a continually changing market.

Long before Major Bull had acquired the prominence in the profession which he now holds, he became interested in the work of the American Foundrymen's Association. His earlier educational training and his wide experience in the industrial field placed him in a position to be of unusual service to the Association at a most critical time. For seventeen years he has exerted the most profound influence upon its affairs.

It was he who accepted from Mr. Seaman the fund, now bearing the donor's name, a portion of the income from which has been used for the preparation of a medal in his behalf. His loyalty and his devotion to the interests of the Association, and his administrative guidance during those earlier days, are responsible in no small degree for the development that has come within the Association in these later years.

His election to the presidency in 1915 and 1916 while in itself a distinct honor, becomes of lesser significance when compared with his continuous endeavor before and since that date in the technical and administrative departments of the Association.

Of these functions, perhaps the most significant is his work in the organization and leadership of the National Research Council Committee on Molding Sand, organized in 1921. It will be agreed, I think, that no branch of the foundry industry has had greater advancement or been productive of such tremendous economies in foundry materials, as has the conservation of molding sand, resulting from the intensive work of this and subordinate committees.

When in 1924, by the present method of succession in office, his term as director was concluded and he retired from active participation in the affairs of the Board of Directors, he concluded a service to the foundry industry of the country that is equaled by few men of his generation.

While thus engaged in his work as director of research and his work with the American Foundrymen's Association, he was also active in the affairs of other scientific societies, more particularly the American Society of Testing Materials.

I conceive that the honor we are now bestowing to be due him altogether for his unremitting and conscientious work through these many years. He has shown force and tact and sympathy. He has modesty, that represents the highest generosity to his associates.

He has shown initiative and determination toward the accomplishments of his ideals. He has that humility that comes of broad knowledge. He has intellectual honesty. He is true to himself and by that token he is true to every interest

that engages his attention. He is loyal to his friends and has a fine sense of humor, always a saving grace.

All these traits were known to "Daddy" Seaman and were

MAJOR R. A. BULL

Mr. Seaman living today I am sure he would most heartily concur in the decision of the Board of Awards.

I will ask Major Bull to rise.

On behalf of the American Foundrymen's Association, as recommended by the Board of Awards and approved by the

Board of Directors, I have the honor to present you The Joseph S. Seaman Medal for your character, your zeal and your accomplishments for the foundry industry of this country.

MAJOR R. A. BULL: Mr. Chairman, Mr. President, Ladies and Gentlemen:

All of you appreciate to some extent the difficulty confronting one who is expected to acknowledge appropriately a distinctive honor. This being so, I know you now feel charitable

THE JOSEPH S. SEAMAN MEDAL

toward me. Because I am kindly disposed toward you, I will make my remarks brief. Later, Dr. Bradley, I am sure, will entertain you suitably. He may happily cause you to forget my inadequate language. But I hope you will remember my profound appreciation.

If I had received previously any honors having remote relationship with that of the Seaman Medal, probably I could do a better job than I am now doing. But never before did I receive any kind of medal for individual merit, barring several that came to me by proxy because I once owned a good dog. Occasionally I crack 120 on the golf course, but so far I have not received a cup. In my school days I took part in numerous athletic contests,

strange as that may now seem to you. Occasionally I got third place; and once in a long while I ran second; but never first. And in those hectic nineties, only the fellows who got first place received medals. The others had to be content with ribbons.

And so now I get my first real medal. I was greatly surprised a few weeks ago when I was notified that the Seaman Medal was to be given to me. I was surprised because no single, very important technical achievement can be credited justly to me. Research in the steel foundry in my own case has meant in the main prosaically taking the chance out of its operations. There has been no poetical tinge to it even of the blank verse kind. Research work is what a steel foundry doesn't do, when it stands still, preparatory to flopping sooner or later into the arms of the sheriff. There is much that is not romantic in such work.

Naturally I have been prompted to review my foundry career. And in doing that I think I found the answer to the question in my mind, and doubtless in yours, as to the main reason for conferring this honor on me. If I have had the privilege of doing anything the results of which were of very valuable significance in advancing the art of founding metals, that thing was serving as president of the A. F. A., when through a combination of circumstances its usefulness was capable of great expansion, dependent on those who managed it. Events showed the wisdom exercised by a group of men of whom I happened to be the nominal leader.

More than in any other way does it satisfy my sense of the fitness of things to consider the Seaman award as a token of recognition of the unselfish, intelligent guidance of the A. F. A. at a critical time, by the twenty-seven men, including myself, who incorporated the Association in 1916; and especially by the six men, including myself, who constituted a working committee that carried the principal burden of reorganization. The results were many and important, including an increase from about $75.00 to something like $12,000.00 within two years, in the assets of the Association. This made it possible for the organization to serve its members as it never had before.

I have referred to a working committee of six men. Officially there were only five who steered the A. F. A. through the

unknown channels we navigated in 1915 and 1916. The sixth and unofficially designated member was he who gave the money to make possible the award you now confer on me. The small committee made demands on Mr. Seaman's time in a way which he could not resist, because of his intense interest.

Of the six men to whom I have referred, one only, Mr. Howell, shares with me tonight the privilege of being alive. Seaman, Speer, Pero, Backert—all past presidents—men to honor by every one who knows the history of this organization; all gone to rewards, we may confidently hope, beyond the realization of living men, including those who receive honors such as you graciously bestow on me.

May I not without any false modesty, unbecoming presumption, or lack of personal appreciation, accept this medal on behalf of all those whose wise leadership established the A. F. A. on a plane of great usefulness to the industry it serves? In doing this, permit me to say that my pleasure is the greater for your choice of the Seaman Medal. I had the honor, as a man many years younger than Mr. Seaman, to be his intimate friend. He sought my advice before he gave the medal fund to the Association. He made me his spokesman and the courier for delivery of $5,000.00 in Liberty Bonds when the fund was established, at a time when ill health prevented his personal presentation of the fund. It was in his home that most of the frequent meetings of the special committee of six men were held, to plan for reorganizing the A. F. A.

For all these reasons, and because "Daddy" Seaman, Major Speer, Jack Pero, Babe Backert, and Alf Howell, according to my way of looking at it, are all honored automatically when you are good enough to honor me, I am proud to accept, Mr. Chairman and Mr. President, the Joseph S. Seaman Medal, which will be treasured as one of my priceless possessions, and a token of esteem of much greater worth than any conceivable thing of purely intrinsic value.

The banquet proceedings were concluded with an address by Dr. Preston Bradley, pastor of the People's Church of Chicago, who spoke on the subject of "Facing the Future."

Report of Executive Secretary-Treasurer

As a result of the change in convention dates from fall to spring, we are going to press with our second volume of transactions during the fiscal year 1927. Volume 34, published in April, contained proceedings for the year ending December 31, 1926. This volume contains proceedings of the three-day convention held in Chicago in June. It is smaller than usual but contains much of value to the casting industry.

When in 1926 it was decided to change from fall to spring meetings to avoid conflict with conventions of allied organizations in which members and exhibitors were interested, it was also decided to hold this year's convention without an exhibit. As this was the first time the exhibit had been omitted since 1906, the plan was generally accepted as an experiment. The results of the Chicago convention, with a registered attendance of 1,097, quite exceeded expectations and demonstrated to the satisfaction of all that the casting industry could stage a purely technical meeting that compared most favorably with meetings of other ranking technical societies.

We believe, however, that the industry suffers a distinct loss when a year is passed over without the big joint convention and exhibit being held, attracting thousands of foundrymen who by attending gain knowledge and inspiration for doing bigger and better things. Furthermore, these events very definitely impress upon users of castings the fact that the foundry industry is progressive and their confidence in castings is increased, something very much needed at this time when other articles such as stampings, forgings and fabricated products are being pushed as substitutes for castings.

Keen competition in the past between various classes of ferrous castings, steel, malleable and gray iron, has furnished the stimulus for improved methods and better products. This new competition should and will result in even greater advances in the art of founding.

A. F. A. must accept its full share of responsibility for collecting and disseminating information which will help the foun-

dry industry to keep step with progress in other industries. With this in mind, the Board of Directors have approved plans for new activities, including an exhibit of quality castings at the 1928 convention and the inauguration of a five-day course of instruction for foundrymen during convention week.

Membership

The big convention and exhibit, the period just preceding and immediately following, are harvest days for new members. Without this stimulus in a year when foundry operations are below the average, membership growth is apt to suffer. It is therefore gratifying to be able to report a steady growth during the first nine months of the year. On December 31, 1926, our book membership was 2,180. Up to October 1st, 239 new members were elected. During the same period there were 63 resignations and 29 dropped as delinquent, making the net gain for the period 147 and the book membership on October 1st, 2,327, the highest in the history of the association. This membership is divided as follows: Class A members paying $12.00 dues, 1,643; Class B, paying annual dues of $7.50, 586; foreign members, paying annual dues of $10.00, 59; juniors, paying annual dues of $5.00, 18; and honorary members, 21.

Finances

The association funds are kept in several accounts as follows: technical department general fund, exhibit department general fund, award funds principal, award funds interest, research savings accounts and reserve fund.

The treasurer's books are audited annually after the close of the fiscal year ending December 31st. The auditor's statement for the year ending December 31, 1926, is shown in Volume 34, published in April of this year.

At the annual board meeting held October 14th, the finance committee presented a report showing the financial condition of the association. Receipts and disbursements for the technical department for the period ending October 31st and estimated expenses and receipts to the end of the year were shown. As no exhibit was held during the year, there was no income for that department except interest from the sinking fund and a few ac-

counts receivable. A loan was authorized for financing this department during the last two months of the year, using sinking fund securities as collateral. On October 1st the sinking fund, including interest, totaled $24,017.94.

Research Funds

The board voted to use the principal and interest in the Rogers Brown research fund, totaling $560.41, toward defraying the cost of preparation of a bibliography on cast iron, prepared under the direction of J. W. Bolton of the subcommittee on cast iron research program. The board also voted to make available for this work the Cleveland research fund, which totals $1,391.78 plus interest to December 31st.

The balance in the molding sand research fund on January 1st was $97.29. A transfer of $1,600.00 from the funds of the department of exhibits was authorized by the board for this work. Expenses to October 31st were $1,418.71, leaving a balance of $278.58.

Special Fund

During July our steel foundry members were asked to subscribe to a special fund toward defraying our share of the cost of a series of tests on phosphorus in steel, conducted under the auspices of the joint committee on investigation of phosphorus and sulphur in steel. The response was gratifying, the subscriptions totaling $1,010.00.

Appreciation

In the short interval between the Detroit and the Chicago conventions, Technical Secretary R. E. Kennedy and his committees produced a splendid program and we acknowledge with sincere appreciation the co-operation of all authors of papers and reports whose contributions contributed to a successful convention.

For the support of President S. W. Utley, Vice President S. T. Johnston, Technical Secretary R. E. Kennedy, all the members of the board and committees thereof, we express hearty appreciation and thanks. Respectfully submitted,

C. E. Hoyt,
Executive Secretary-Treasurer.

Minutes of Annual Meeting of Board of Directors

AMERICAN FOUNDRYMEN'S ASSOCIATION

EDGEWATER BEACH HOTEL, CHICAGO, JUNE 9, 1927

President S. W. Utley presiding.

Roll Call

The following were present: President S. W. Utley, Vice-President S. T. Johnston, Technical Secretary R. E. Kennedy, Directors G. H. Clamer, A. E. Hageboeck, Wm. J. Nugent, Fred Erb, C. E. Hoyt, L. W. Olson, H. S. Simpson, N. K. B. Patch, A. B. Root, Jr., S. C. Vessy, L. C. Wilson, and Directors-elect E. H. Ballard and H. Y. Carson.

Absent, Directors J. E. Galvin, R. A. Nourse, J. L. Jones, M. W. Henley and Director-elect W. D. Goldsmith.

This meeting, held on the closing day of the 31st Annual Convention, was preceded by the Annual Alumni Dinner and was attended by the following who remained for the Board meeting: B. D. Fuller, V. E. Minich, R. A. Bull, C. R. Messinger, L. L. Anthes, C. S. Koch and A. E. Howell.

In calling the meeting to order President Utley expressed for the officers and members of A.F.A. appreciation of the work of the Chicago General Committee and requested General Chairman W. J. Nugent to thank the members of all committees for hospitality shown and for the cooperation that had contributed so much to the success of the Convention just closed.

It was moved that reading of minutes of the annual meeting of the Board held on December 7, 1926, which appear in bound volume of Transactions No. 34, be waived. Motion prevailed.

President Utley announced that in calling an annual Board meeting on the closing day of the Convention it was realized that it would not be possible for the Board to hear reports, transact the usual business and organize, and that it would be necessary to hold an adjourned meeting, probably some time in the early fall. He therefore would entertain a motion that the regular order of business for the annual meeting be waived, to be resumed at the adjourned meeting to be held in pursuance to the call of the President, and that the Board proceed with special business. The motion was made, seconded and carried.

Report of Committee on Convention and Exhibits

Executive Secretary Hoyt reported that the Committee on Convention and Exhibits, authorized by the Board to select a city and determine the time of the 1928 Convention and Exhibit, had by letter ballot unanimously decided to hold the next Annual Convention and Exhibit in the city

of Philadelphia, the week of May 14, 1928. On motion the report was accepted.

Report for Board of Awards by the Secretary

The Secretary reporting for the Board of Awards stated that on April 15 a letter ballot was submitted to the Directors for approval of the unanimous recommendation of the Board of Awards that the Joseph S. Seaman Gold Medal of the American Foundrymen's Association be awarded to Major Robert Alexander Bull, presentation to be made at the annual Banquet of the Association, June 8, 1927. The Secretary further stated that the ballot was unanimous in favor of the recommendation, and that the Joseph S. Seaman Medal and Certificate had been presented to Major Bull at the Banquet on the previous evening.

The Secretary reporting further for the Board of Awards submitted a statement on award funds, read extracts from the conditions of the deeds of gift, and recommended that the Board of Awards and the Board of Directors consider other uses for the award interest fund than the giving of major awards.

On motion by Mr. Olson, seconded by Mr. Clamer, the report was accepted

Recommendations of Apprentice Training Committee

The Secretary read a resolution adopted at the meeting of the Apprentice Training Committee held Monday, June 6th, with recommendations for offering prizes for apprentice contests in molding and pattern making. On motion duly seconded the resolution was referred to the Board of Awards.

Report of Board of Awards by the Chairman

Mr. Root, Chairman of the Board of Awards, submitted the following report:

The report of the Apprentice Training Committee has been considered by the Board of Awards in anticipation of its being referred to them. The award funds are in very good condition and the committee have certain recommendations to make, not with the idea of using these funds in order that they will not accumulate, but in order to advance the principles for which the funds were made. We will not use the entire income from the funds in any one year, but the first move should be made this year towards the use of the annual interest and we feel that as the years pass the use of the funds will increase in a broader way for increasing benefit to the Association. The Board of Awards therefore begs to submit the following report for the use of the income from the funds for the year 1927-28.

1. In compliance with the spirit of the request of the Apprentice Training Committee, and as referred to the Board of Awards by the Board of Directors, we recommend the making of awards in the apprentice contests on iron and steel molding and pattern making of a wrist watch suitably engraved for first prize, of $25.00 in cash for second prize, and of $10.00

in cash for third prize; each of these prizes to be accompanied by a simple certificate bearing the name of the donor of the award fund from which the interest is taken.

2. The Board of Awards recommends that a cash award of $100.00 in gold may be made for each of the three best papers presented at the 1928 Convention in the following subjects: gray iron, steel, malleable, non-ferrous and general foundry subjects. These cash awards to be accompanied by a simple certificate. The manner of selection of these papers will be left to the discretion of the Board of Awards.

3. The Board of Awards recommends that the Board of Directors authorize it to engage the services of some outstanding authority for the presentation of a paper at the 1928 Convention.

Following a lengthy general discussion each recommendataion was separately acted upon and adopted as submitted.

Report for Committee on International Relations

The Secretary reported that following the International Foundrymen's Congress in Detroit in September, 1926, there had been organized in Europe the European International Committee of Foundry Technical Associations, and that at a meeting held in Brussels on April 9, 1927, the following countries were officially represented: Belgium, France, Germany, Great Britain, Holland and Spain; that the United States was represented by Mr. Vincent Delport, European Representative of the A.F.A. Committee on International Relations, who was present as an observer and who had submitted a report summarizing the proceedings as follows:

First, the official associations of each country shall be represented on the International Committee by two delegates, suitably chosen.

Second, that the International Committee would only give its patronage to one exhibition each year, to be held in connection with that year's Congress.

Third, that an International Congress will be held every three years, in which the A.F.A. will be invited to officially participate, these congresses to take place in rotation in Great Britain, Germany, France and United States; that in the intervening years one congress should take place in one of the European countries, in which America would not participate in an official manner.

Fourth, that the International Committee will meet once a year on the occasion of that year's congress; that its President will be nominated for one year and shall be chosen from one of the nations other than that organizing the congress; and that each country should contribute the sum of $25.00 towards the expenses of the Secretary.

Fifth, that expenses incurred in respective hospitality may be limited to the President and Secretary of each association and the authors or readers of official papers, and that each country would only present one exchange paper at each congress.

Sixth, that when the A.F.A. joins the committee, it will be represented by the Chairman of its Committee on International Relations and by its European Representative, and that the American vote would suffice to veto any decision that might be against American interests.

The Secretary reported that H. Cole Estep, Chairman of the Committee on International Relations, had corresponded with all the members of his committee and they were unanimous in feeling that it was now time that the A.F.A. became officially a member and accept the invitation to membership which had been extended officially by Mr. Paul Ropsy, President of the International Committee.

Mr. Root moved that the Board accept the invitation to membership on the International Committee of Foundry Technical Associations and that the President be authorized to appoint representatives. Motion seconded by Mr. Clamer and carried.

Third International Foundrymen's Congress

The Secretary reported that an official invitation had been received from the Institute of British Foundrymen, signed by the President and Secretary, officially inviting the American Foundrymen's Association to participate in the 3rd International Foundrymen's Congress to be held in London from June 11 to 15, 1929.

On motion by Mr. Clamer, seconded by Mr. Howell, the invitation was accepted and the Secretary authorized to notify the President and Secretary of the I.B.F.

Greetings from England and Belgium

President Utley announced that in addition to the cablegram of greetings from the Belgian Association read at the Banquet, he had received a cablegram from Mr. Faulkner, President of the Institute of British Foundrymen, sending cordial good wishes for a successful meeting.

On motion the President was authorized to officially acknowledge these messages of good will.

Report of Committee on Distribution of Preprints

Mr. Nugent, Chairman of the Committee on Distribution of Preprints, submitted the following report:

Your committee recommends that the practice of mailing copies of all preprints to all members be discontinued and that the following plan be adopted:

First, that the Secretary be instructed to address a communication to the members stating that hereafter the mailing of preprints would be by groups as follows: gray iron, malleable, non-ferrous and steel, and that the members would be sent only those groups which they elected to receive, plus papers on general subjects such as sand, apprenticeship, costs, etc.

Second, that in the event any members fail to elect to receive groups in the manner provided, the Secretary be instructed to mail to such

members preprints for the branch of the industry in which the member is actively engaged, namely, gray iron, malleable, non-ferrous or steel.

Third, that it be understood that members desiring copies of all preprints should be entitled to receive them if they so elect.

Mr. Root moved that the report be accepted and put into effect for the coming year. Motion seconded by Mr. Hageboeck and carried.

Apprentice Molding Contest

The Secretary read a report submitted by the Judges of the Apprentice Molding Contest, which had been presented at the annual meeting of A.F.A. on June 8th and referred to the Board of Directors. It was moved that the report be accepted and that A.F.A. Apprentice Molding Contest prizes be awarded as follows:

Gray Iron Section

1st Prize—H. E. Stromberg, General Electric Co., Lynn, Mass.
2nd Prize—Y. Sawtelle, General Electric Co., Lynn, Mass.
3rd Prize—W. Urquhart, General Electric Co., Lynn, Mass.

Steel Section

1st Prize—Carl H. Oleson, Pettibone Mulliken Co., Chicago.
2nd Prize—Andrew Bottoni, Falk Corp., Milwaukee, Wis.
3rd Prize—Joseph Buneta, Falk Corp., Milwaukee, Wis.

Apprentice Pattern Making Contest

The Secretary read a report submitted by the Judges of the Apprentice Pattern Making Contest. On motion the report was accepted and the Board authorized the awarding of prizes as follows:

1st Prize—Siegfried V. Hanson, Pettibone Mulliken Co., Chicago.
2nd Prize—Joseph L. Asp, Pettibone, Mulliken Co., Chicago.
3rd Prize—Lester G. Furber, Brown & Sharpe Mfg. Co., Providence, R. I.

Pig Iron Qualities

The Secretary read the following resolution, which was passed at a members' session, presented at the annual business meeting and on motion referred to the Board of Directors:

BE IT RESOLVED, That it is the consensus of this assembly that a cooperative study of the effects of varying blast furnace operations on the character of the pig iron made under changing blast furnace conditions, and on the castings made therefrom, be conducted under the supervision of the Department of Commerce, with an advisory committee consisting of representatives of the national technical associations, such as the A.F.A., American Pig Iron Association, A.I.M.&M.E., and the A.S.T.M.

Following discussion it was moved that action by the Board be deferred until information was available as to plan of procedure and it could be learned to what extent the Department of Commerce would support the

plan and the cooperation that would be given by other societies. Motion seconded by Mr. Olson and carried.

Report of Election of Officers and Directors

The Secretary reported that the election of S. W. Utley as President and S. T. Johnston as Vice-President for terms of one year each, and E. H. Ballard, H. Y. Carson, W. D. Goldsmith, A. E. Hageboeck and W. J. Nugent as Directors for terms of three years each, was confirmed at the annual business meeting, Tuesday, June 7th, their terms of office to begin as provided for in Section 4, Article X of the By-Laws.

Report of Steel Session

Major Bull, Chairman of the Steel Session held Wednesday P. M., June 8th, reported that A. H. Jameson, Chairman of the A.F.A. Committee on Steel Castings and by virtue of his office the A.F.A. representative on Committee A-1 and its sub-committees VIII and XXII of the A.S.T.M., had submitted a report. This report was in the nature of a protest to the proposed advancement of Tentative Specifications A87-22T to Standard Specifications, setting forth in detail objections to adoption, and that following discussion the following resolution was adopted by unanimous vote:

RESOLVED: That it is the consensus of opinion of the steel foundrymen attending the 31st Annual Convention of the American Foundrymen's Association, in regular meeting assembled, that it would be unfair and unscientific for the American Society for Testing Materials to discriminate in eliminating any steel making process, or to establish mandatory limits for carbon, manganese, or silicon while specifying physical properties, in any tentative or standard specifications for steel castings.

Major Bull stated that in the interest of harmony he believed this Board should authorize the transmission of this resolution to the Executive Committee of the American Society for Testing Materials, requesting that they give their earnest consideration to the views expressed at the session.

After discussion the Board by unanimous vote expressed its approval of the resolution as adopted at the steel session and authorized the Secretary to transmit this resolution to the Executive Committee of the A.S.T.M.

President Utley called attention to the very fine spirit that had been shown by the Electric Steel Founders' Research Group in opposing the adoption of specifications that would impose a penalty on their competitors in the steel casting industry.

Invitation to 25th Anniversary of the A.S.T.M.

The Secretary stated that an invitation had been received to send an official representative to the 25th Anniversary Dinner of the A.S.T.M., which would be held during their Annual Convention at French Lick, June 20 to 24. It was moved by Mr. Erb, seconded by Mr. Patch, that Mr.

Clamer be delegated as the official representative of the A.F.A. at the A.S.T.M. Convention. Motion carried.

Committee on Placing Weights of Castings on Blue Prints

Mr. Root, A.F.A. representative on the U. S. Chamber of Commerce Committee to consider the Placing of Weights of Castings on Blue Prints, reported that no progress had been made during the past six months and asked for instructions. He was requested to communicate with the chairman and report at the next meeting of the Board, with recommendations as to our continued participation in this movement.

Adjournment

On motion the meeting adjourned subject to call of the President.

Respectfully submitted,

C. E. Hoyt, Executive Secretary.

Approved: S. W. Utley, President.

Minutes of Adjourned Annual Meeting, 1926-27 Board of Directors

Mansfield-Leland Hotel, Mansfield, Ohio

9:30 A. M. Friday, October 14, 1927

President S. W. Utley presiding.

Roll Call

The following responded to roll call: President S. W. Utley, Vice-President S. T. Johnston, Technical Secretary R. E. Kennedy, and Directors G. H. Clamer, J. E. Galvin, A. E. Hageboeck, R. A. Nourse, W. J. Nugent, Fred Erb, C. E. Hoyt, J. L. Jones, L. W. Olson, H. S. Simpson, M. W. Henley, N. K. B. Patch, A. B. Root, Jr, and S. C. Vessy. Absent, L. C. Wilson.

Directors-elect H. Y. Carson and W. D. Goldsmith, and past presidents W. R. Bean, B. D. Fuller and C. S. Koch were also present.

Reading of Minutes

The minutes of the Annual Meeting held at the Edgewater Beach Hotel, June 9, 1927, were approved as read.

Report of Executive Secretary

The Executive Secretary read his annual report. On motion duly seconded, the report was accepted and ordered placed on file.

Report of Treasurer

The Treasurer submitted a report of Association finances for the period January 1st to September 30th. On motion duly seconded, the report was accepted and ordered placed on file.

Report of Finance Committee

The report of the Finance Committee, consisting of S. W. Utley, S. T. Johnston and A. B. Root, Jr., was submitted by Mr. Root. He presented a statement of receipts and disbursements for the technical department from January 1st to September 30th, and estimated receipts and expenses to December 31st.

Reporting for the exhibit department, he pointed out that due to no exhibit being held during the year, the only income had been from 1926 accounts receivable and bank interest, amounting to $3,221.12, and that funds would be necessary to finance the preliminary expenses of the Philadelphia Exhibit next year. The committee recommended that a loan of $8,000.00 be authorized for this purpose, using as collateral the reserve fund, which totals $24,017.94.

On motion by Mr. Vessy, duly seconded, the report of the Finance Committee was accepted.

Mr. Clamer moved that the recommendation of the Finance Committee for financing the exhibit department be approved and that the Secretary-Treasurer be authorized to borrow funds to the amount of $8,000.00. Motion seconded and carried.

Report of Executive Committee

The Chair stated that no meetings of the committee had been held since the last Board meeting and that the reports of the Technical Secretary and Manager of Exhibits would go over until the new Board meeting. He then called for reports of such standing and special committees as had not been disposed of at the June meeting.

Committee on Placing Weights on Blue Prints

Mr. Root, the A.F.A. representative on the U. S. Chamber of Commerce Committee, made a statement of the difficulties encountered, saying that Chairman Hunter of the Department of Commerce had stated that it seemed a hopeless job to secure any action and that he would therefore recommend that the A.F.A. withdraw participation on the committee until such time as it should become active again.

It was moved by Mr. Patch that Mr. Root's recommendation be approved. Motion seconded by Mr. Hageboeck and carried.

Sub-committee on Pig Iron Qualities

The Chair announced that at the June meeting it was decided to defer action on the resolution passed at a members' session until it could be

learned to what extent the Department of Commerce and other societies would cooperate, and called on Mr. Jones, Chairman.

Mr. Jones made a general statement covering activities of the A.F.A. committee following the June meeting, stating that the Secretary of the A.S.T.M. had said that they had no money available for such work, that while the A.I.M.&M.E. had discussed a cooperative study of blast furnaces at its last meeting, it had made no plans for carrying on the work, and that until further information was available as to a practicable plan of operation, the A.F.A. committee was not ready to recommend any program for active participation.

Mr. Jones reviewed somewhat the work that had been done in Germany by the German Foundrymen's Association and the manufacturers of pig iron, stating that while some results had been obtained, they were not altogether satisfactory and that new methods of approaching the question would have to be devised. Mr. Jones expressed appreciation to Dr. Koerber of the German Foundrymen's Association, who had furnished information about the results of their work, and also made special mention of the help of committee members R. S. MacPherran, E. J. Lowry and Max Kuniansky, and of the consulting member, Dr. Richard Moldenke.

A lengthy discussion followed, participated in by a number of the Directors, following which it was moved that the matter be referred back to the committee with the suggestion that they try to outline some plan of experimentation or investigation that could be followed. Motion duly seconded and carried.

Appreciation

Mr. Olson, addressing the Chair, stated: "When this meeting adjourns, the terms of office of three of our members will expire; Mr. Clamer, who has served us well as Director, Vice-President and President, and Mr. Galvin and Mr. Nourse, who have served as Directors for three years. It would be fitting for this body to express their appreciation to these gentlemen for the interest they have taken in advancing the activities of this Association."

Motion seconded by Mr. Vessy and unanimously carried.

Approval of Acts of Committees of the Board

Mr. Henley moved that the Board approve all acts of committees of the Board during the year. Motion seconded and carried.

Adjournment

Mr. Clamer moved that the final meeting of the 1926-27 Board stand adjourned. Motion seconded and carried.

Respectfully submitted,

C. E. Hoyt, Executive Secretary.

Approved: S. W. Utley, President.

Minutes of First Meeting, 1927-28 Board of Directors

MANSFIELD-LELAND HOTEL, MANSFIELD, OHIO

FRIDAY, OCTOBER 14, 1927

President S. W. Utley presiding.

Roll Call

The following responded to roll call: President S. W. Utley, Vice-President S. T. Johnston, Technical Secretary R. E. Kennedy, and Directors Fred Erb, C. E. Hoyt, J. L. Jones, L. W. Olson, H. S. Simpson, M W. Henley, N. K. B. Patch, A. B. Root, Jr., S. C. Vessy, H. Y. Carson, W. D. Goldsmith, A. E. Hageboeck and W. J. Nugent. Absent, L. C. Wilson and E. H. Ballard.

Others present were W. R. Bean, B. D. Fuller, C. S. Koch, G. H. Clamer, J. E. Galvin and R. A. Nourse.

Organization of New Board

The Chair announced that the Board would proceed to organize by the election of officers and members of the Executive Committee in accordance with the provisions of the By-Laws, and that he would appoint Messrs. Johnston, Patch, Carson and Vessy members of the Nominating Committee.

Report of Nominating Committee

The committee reported as follows:

First, For four members of the Executive Committee, to serve with the President, Vice-President and Executive Secretary, we nominate W. J. Nugent, L. W. Olson, A. B. Root, Jr., and L. C. Wilson.

Second, The committee recommends that the offices of Executive Secretary, Treasurer and Manager of Exhibits be combined in one and nominates C. E. Hoyt for the combined offices.

Third, For the office of Technical Secretary we nominate Robert E. Kennedy.

Mr. Hageboeck moved that the report of the committee be accepted and that the Chair cast one ballot for the nominees named by the Nominating Committee. Motion seconded and carried, whereupon the Chair announced that the unanimous ballot had been cast for the Board and declared all candidates elected to the respective offices for which they had been named in the report of the Nominating Committee.

Salaries

The Chair called for the report of the Finance Committee on recommendations for salaries and compensations for the ensuing year. Mr. Root reported as follows:

That the salary of C. E. Hoyt as Executive Secretary-Treasurer be

$5,500.00 per year, $2,750 to be paid by the technical department and $2,750.00 by the exhibit department.

That the salary of R. E. Kennedy as Technical Secretary be $4,800.00 per year, to be paid by the technical department.

That the salary of C. E. Hoyt as Manager of Exhibits be $6,500.00 per year, to be paid from the funds of the department of exhibits.

That the salary of Miss J. Reininga, Assistant to the Secretary-Manager, be $250.00 per month, $75.00 to be paid by the technical department and $175.00 by the department of exhibits.

That the President and Executive Secretary be authorized to employ such office assistance as is necessary to take care of Association activities.

Mr. Vessy moved that the report of the Finance Committee be accepted and the salary recommendations authorized. Motion seconded and carried.

Disbursement of Funds

Resolved, That checks for the withdrawal of funds deposited in the name of the Association in the Harris Trust & Savings Bank and Chicago Trust Co., Chicago, and Central National Bank Savings & Trust Co., Cleveland, be signed by the President, S. W. Utley, or Secretary-Treasurer, C. E. Hoyt, and countersigned by President S. W. Utley, or Vice-President S. T. Johnston.

Be It Further Resolved, That the resolutions required by the aforesaid mentioned banks, authorizing the withdrawal of funds of the Association in accordance with the above resolution, are hereby approved and adopted.

Be It Further Resolved, That both officers of the Association are hereby authorized to open an account in the convention city for a special convention fund, they to determine how this account shall be opened and the signatures required for the withdrawal of said fund.

Be It Further Resolved, That the Board authorize a Secretary-Manager's petty cash fund of $500.00, said fund to be reconciled at the end of each month by a full statement of expenditures.

On motion by Mr. Vessy, duly seconded, the above resolutions were unanimously adopted.

Treasurer's Bond

On motion by Mr. Root duly seconded, the following resolution was unanimously adopted:

Resolved, That in accordance with provisions of the By-Laws, the Treasurer shall be required to give a bond to the amount of $5,000.00, the premium on said bond to be paid by the Association.

Committee Meeting Expenses

On motion by Mr. Erb, duly seconded, the following resolution was unanimously adopted:

Resolved, That the Secretary-Treasurer be authorized to reimburse Directors and committee members for traveling expenses for attendance at

any regularly called Board or committee meetings, except such meetings as are held at the place and during the week of the annual convention of the Association.

Audit of Books

Mr. Patch moved that the President be authorized to engage an auditor to audit the books as of December 31, 1927. Motion seconded and carried.

Committee Appointments

On motion by Mr. Vessy, seconded by Mr. Henley, the President was authorized to make all appointments for standing and special committees not provided for in the By-Laws or by special act of the Board.

Report of Technical Secretary

Technical Secretary R. E. Kennedy submitted a report reviewing the work on the bibliography on cast iron, reported briefly for the Joint Committee on Foundry Refractories, announced that John Howe Hall would present the British exchange paper and H. A. Schwartz the French exchange paper, and that bound volume of Transactions No. 35 for the year 1927, consisting of about 550 pages, was being printed.

He then outlined a technical program for the 1928 convention, stating that in addition to the regular sessions it was proposed to organize short courses of talks and discussions on fundamental foundry practices. He also submitted a new method of conducting the apprentice molding and pattern making contests that had been proposed.

It was moved that the report of the Technical Secretary be accepted, that the outline of a technical program be approved, and that the Board approve of the plan submitted for organizing short courses and that this be offered without any registration fee. Motion seconded and carried.

Bibliography on Cast Iron

Mr. Utley, commenting on Secretary Kennedy's progress report on the bibliography on cast iron, stated that the Finance Committee had authorized the use of the principal and interest in the Rogers Brown Research Fund, amounting to $560.41, in accordance with action of the Board at the meeting on December 7, 1926.

He stated further that it was estimated that the cost of summarizing the bibliography would be $2,000.00, and the Finance Committee recommended that the Cleveland Research Fund, amounting to approximately $1400.00, be applied toward the cost of the work, adding that they believed that the donors and contributors of these research funds would feel that the money could not have been used for a better purpose and that it was hoped that the results obtained would stimulate further contributions for similar work under the direction of committees of A.F.A.

On motion the recommendations of the committee were accepted and the use of the Rogers Brown and Cleveland Research Funds approved.

Reinvestment of Reserve Fund

Mr. Hoyt stated that the $18,500 in U. S. Second Liberty Loan 4¼s in the Reserve Fund, called for November 15th, had been exchanged for new Five-Year 3½% U. S. Treasury Notes, and suggested that consideration be given to reinvesting in bonds that would give a bigger yield than 3½%.

Mr. Olson moved that the reinvestment of this money be left in the hands of the Finance Committee. Motion seconded and carried.

Reinvestment of Award Funds

Mr. Hoyt reported that the $11,000 in U. S. Second Liberty Loan 4¼s in the Award Fund, which were called for November 15th, had been exchanged for new Five-Year 3½% U. S. Treasury Notes. The investment of the Award Fund bonds is in the hands of the Board of Awards, but the agreement with the Trust Company provides that securities may be withdrawn only on a joint written order by the President and Secretary-Treasurer, accompanied by a certified copy of a resolution of the Board of Directors.

On motion by Mr. Olson duly seconded, the following resolution was unanimously adopted:

Resolved: That the Board of Directors of the American Foundrymen's Association, in meeting October 14, 1927, ratifies the exchange by the Harris Trust & Savings Bank of $11,000 in Second Liberty Loan 4¼s, due 1942 and called November 15, 1927, for $11,000 par value Five-Year 3½% U. S. Treasury Notes at 100⅛, with interest in full on the Second 4¼s to November 15, 1927.

Mr. Root, Chairman of the Board of Awards, requested action by the Board of Directors authorizing the Harris Trust Company, custodians of the award principal funds, to make such investments and reinvestments as may be recommended from time to time by the Board of Awards.

On motion by Mr. Vessy, seconded by Mr. Nugent, such authorization was unanimously approved.

Report of Manager of Exhibits

Mr. Hoyt submitted a report for the Committee on Convention and Exhibits, outlining a program for the 1928 meeting for the Board's consideration. After discussion action was taken as follows:

(a) The dates of the Convention shall be Monday, May 14, to Friday, May 18, inclusive. The formal opening session of the Convention shall be 10:00 A. M. Tuesday, May 15, with Monday devoted to registration, committee meetings and exhibits.

(b) The official opening of Exhibits shall be 10:00 A. M. Monday, May 14. Opening hour each day thereafter 9:00 A. M., official closing hour 5:00 P. M., with Exhibits open one evening as provided for by the Convention and Exhibits Committee.

(c) Entertainment shall be limited as recommended by the committee,

the handling of same to be worked out between the Convention and Exhibits Committee and the Philadelphia Entertainment Committee to their mutual satisfaction.

(d) A special program feature for Charter Members shall be provided under the direction of a committee to be appointed by the President.

(e) Provision shall be made for an exhibit of castings as outlined, if, in the opinion of the committee, same is practicable.

(f) The price of exhibit space shall range from $1.00 per square foot minimum, which shall be applied to the deepest booths, to $1.15 maximum, which shall be applied to the shallowest booths, with 20% additional charged for corners.

(g) Approval of recommendation of the committee that morning sectional meetings be held at the headquarters hotel and general afternoon sessions, if feasible, at the Commercial Museum.

Questionnaire on Gray Iron Casting Industry

It was moved that the Board endorse the movement of the Department of Commerce in collecting data covering the gray iron foundry industry and authorize the cooperation of the Secretary's office. Motion seconded and carried.

1928 Nominating Committee

It was moved that in accordance with authority vested in the Board, as provided in Article 9, Section 1 of the By-Laws, provision be made for the election of four members and four alternate members of the 1928 Nominating Committee by letter ballot of the members.

It was further moved that the Board should select eight members whose names, when acceptances had been obtained, should appear on the ballot together with the name of any other member nominated by five or more members of the Association, the four members receiving the largest number of votes to be members of the Nominating Committee and the four next highest to be alternate members.

Motion prevailed, whereupon each Director placed a name in a hat from which the names of eight members were taken by lot.

Authority of Executive Committee

On motion duly seconded, it was resolved that the Executive Committee be empowered to act for the Board in the interim between Board meetings on all matters requiring Board action.

Adjournment

The Chair announced that the program for the afternoon had been arranged by Mr. Olson and that all who wished to do so would visit the plant of the Ohio Brass Company and those who preferred to play golf would be the guests of Mr. Olson at the Westbrook Country Club, where all would be the guests of Mr. and Mrs. Olson for dinner, and that a motion would be in order to adjourn until evening.

On motion duly seconded, the meeting was adjourned until evening.

Evening Meeting

Following dinner at the Country Club the Board meeting reconvened at the hotel. President Utley introduced Mr. A. F. Jensen, President of the Hanna Engineering Works, Chicago, and Chairman of the Publicity Committee of the Foundry Equipment Manufacturers' Association, who gave a talk on the subject "Creating a Foundry Consciousness." Mr. Jensen said in part as follows:

"I am sure the Foundry Equipment Manufacturers' Association appreciates your finding a place in your program for us, particularly in a business session so crowded with detail as an annual meeting. The Foundry Equipment Manufacturers' Association is vitally interested in developing this Foundry Consciousness, or, if it exists, to maintain it. The F.E.M.A. is considering what line of work of general benefit to the foundry industry and to the foundry equipment manufacturing business could be undertaken and by whom the responsibilities and costs thereof should be borne. That is a matter for discussion. In the final analysis the merchandising problems of the foundry are our problems. The foundries' decreased volume is reflected in our business.

"Industrial conditions are changing and in order to survive, every industry must adapt itself to meet the new conditions. I really believe that the engineering schools offer one avenue of participation to the American Foundrymen's Association, an opportunity for some educational work as to the place of the foundry in American Industry.

"The F.E.M.A. is extremely anxious to cooperate and is open for suggestions. Just how we can meet the situation we do not know, but perhaps a meeting of a committee from your organization and a committee from the Equipment Association might make progress.

"I hope that I have conveyed to you some idea as to the need for this educational work, because it is back in our technical schools that you are training your future executives."

The Chair thanked Mr. Jensen, on behalf of the Directors, for his kindness in coming and for the talk given.

The Secretary read a letter from the Secretary of the Foundry Equipment Manufacturers' Association, including copy of a resolution adopted by that Association, addressed to the American Society of Mechanical Engineers, protesting their sponsoring a publicity program advocating the commercial advantages of welded parts versus castings. General discussion followed on the subject of propaganda tending to discredit castings.

It was moved that the appointment of a committee to consider this matter be authorized.

The question of convention entertainment features was discussed and all present were in favor of very decidedly limiting the entertainmnt offered and permitted during convention week.

President Utley, on behalf of the Directors, expressed appreciation to Mr. Olson for his hospitality and efforts which had contributed to a suc-

cessful and enjoyable meeting, and on behalf of the officers expressed appreciation to the Directors for attendance at the meeting, there being only two Directors absent.

On motion duly seconded, the meeting adjourned.

Respectfully submitted,

C. E. Hoyt, Executive Secretary.

Approved: S. W. Utley, President.

Report of Technical Committees Presented at Annual Business Meeting

PRESIDENT S. W. UTLEY: This is the thirty-first annual meeting of our association and marks the thirty-second year of its life. Organized in 1896, at the time of the first convention in 1897 we had a membership of 486. Like most associations, our growth during the first ten years was very slow, resulting in an increase of but 10 per cent, with a total membership of 532 in 1907. Another decade brought a membership of 1,017, almost double what it was at the beginning, while our present membership of 2,300 represents an increase of 125 per cent over that of ten years ago, and is 4.7 times the membership at the end of the first year.

The plan adopted a short time ago, providing for individual as well as firm membership, helped materially in increasing the number, but in view of the fact that there are approximately 5,800 foundries in the country, many of them employing many superintendents and foremen who are eligible for our membership, there is still ample room for growth before the saturation point is reached.

More striking, perhaps, than this is the growth in our committee activities, which in an organization of this kind represent the real index of the attempt to make progress. Ten years ago we had seventeen committees and sub-committees, with a total membership of 64 men. As against this today we have forty-two committees, and in addition, representation on seventeen committees of other organizations, a total committee personnel of 290, an increase of 350 per cent.

This convention marks the first attempt to hold such a gathering without an exhibit since 1906, and can be considered only as an experiment, brought about by rather unusual conditions. In view of the large number of conventions which are being held in the Fall and the added competition for the relatively few ex-

hibit buildings in the country which are of sufficient size to take care of our needs; the competition with the state fairs, whose grounds alone in many of the cities are adequate to take care of our exhibits; the difficulty encountered with weather conditions the last few years; and the fact that the convention coming so soon after the vacation period placed an undue hardship on many of our exhibitors, caused the Board last year to feel that it was wise to change the date again to the Spring of the year. With this decided upon, it was felt to be quite impossible to have another large exhibit so soon after the one held in Detroit, and it was therefore deemed best to try holding a convention this Spring without an exhibit. From the interest so far manifested, your officers feel that this convention will prove to be entirely successful, and when the size of our membership is considered, that both the interest and the attendance will not compare unfavorably with similar meetings of such large organizations as the National Association of Manufacturers or the United States Chamber of Commerce.

But the mere holding of meetings, the reading of papers thoughtfully and carefully prepared, the painstaking work of committees conscientiously studying questions such as vex the industry, do not mark the highest degree of success for an organization such as ours. Unless we can make these thoughts a part of the industry itself; unless they are taken over and vitalized by the industry and bring about the improvement of our practice and of our product, we have fallen far short of what we should accomplish. If we succeed only in spoiling large quantities of white paper with printers' ink, we have failed of our purpose, and proven ourselves to be of no more value than many organizations we see around us.

It is quite true that beyond a certain point we are powerless to advance in this direction. It would no more be possible than it would be desirable to try to force our members to use any method or information which we may devise or ascribe. We can only call to their attention the fact that here is something which has succeeded for someone else and may be of help to them, but I feel that in this busy world, where all are so driven with daily tasks and have so little time for constructive thinking, we should

be remiss in our duty if we did not constantly remind ourselves of the benefits which may come to all by cooperative working along technical lines and through cooperative study of the underlying principles of our industry.

With the thought in mind of emphasizing this situation and of impressing upon ourselves the fact that the work of this Association is not that of efficient secretaries, a couple of officers and some directors, but rather of a great many committees and nearly three hundred conscientious, hard-working committeemen, I have asked the chairmen of a few of these committees to make a part of my report, telling you of the status of their work.

JOINT COMMITTEE ON PATTERN EQUIPMENT STANDARDIZATION

D. M. AVEY: The Joint Committee on Pattern Equipment Standardization is sponsored by the American Foundrymen's Association and numbers in its personnel representatives from the following societies:

American Society for Testing Materials,
National Association of Purchasing Agents,
Electric Steel Founders' Research Group,
Foundry Equipment Manufacturers' Association,
Malleable Iron Research Association,
Steel Founders' Society of America.

Representatives from these societies form the general committee. Three active sub-committees have been organized as follows:

One on Patternmaking, headed by W. F. Grill; one on Pattern Mounting, headed by Jas. Murphy; and one on Flask Sizes, headed by W. J. Kihn.

The standard pattern and corebox color marking which was approved by the committee and by the interested organizations, has been given wide distribution and is in general use practically throughout this country. During the present year the definite policy of putting forward recommended practices rather than to attempt a general standardization of pattern practice has been established. Under this policy recommended practices under the following headings have been approved by the committee:

Marking gaged surfaces and locating parts on patterns.

Markings indicating chilled surfaces and metal inserts on patterns.

Color ingredients of coating materials for marking patterns.

Uniform types of pattern letters.

Marking for loose pieces for patterns and core boxes.

A schedule of sizes for fillets.

A lug design for match plates.

Position of vibrator holes in match plates.

Minimum thickness of pattern plates.

Yesterday at a meeting of the representatives of the subcommittees and the General Committee it was decided to discontinue the Subcommittee on Pattern Making and to concentrate the work of the Subcommittee on Pattern Mounting and the Subcommittee on Flask Sizes upon the recommendation of established practice for pin centers, pin sizes and mounting. It was also decided that information should be gathered upon existing ranges of standard size flasks, this information to be tabulated and made available through a paper at the next convention of the American Foundrymen's Association.

A. F. A. Representative on Joint Committee on Investigation of Effects of Phosphorus and Sulphur in Steel

R. A. Bull: Since our 1926 convention the activities of the Joint Committee on the Investigation of the Effects of Phosphorus and Sulphur in Steel, in so far as they are of interest to steel foundrymen, relate to the testing program for determining the influence of phosphorus in steel castings. It has been decided to restrict this investigation to the testing of laboratory specimens; to use acid open-hearth steel; to employ two grades of steel from the standpoint of carbon content, viz., .25 per cent and .45 per cent; to make the lower carbon steel in five lots with respect to phosphorus content, viz., .025 per cent, .04 per cent, .06 per cent, .07 per cent and .10 per cent, and the higher carbon steel in three lots, containing .025 per cent, .05 per cent and .07 per cent of phosphorus. All lots of steel are to contain approximately .70 per cent manganese, .35 per cent silicon, and .045 per cent sulphur, with no special alloys present. There will be ten-

sion, impact, hardness, fatigue, compression, and torsion tests, all at normal temperatures, after the specimens are annealed, normalized, and normalized and drawn. Thus data will be accumulated for each of three heat treatments.

It has been roughly estimated that $1,500.00 may cover the expense of the tests. The Steel Founders' Society has generously contributed $750.00. The balance will be obtained from steel casting concerns not affiliated with that society.

This report in greater detail will be presented at the Steel Session tomorrow.

Committee on Corrosion of Metals

H. Y. Carson: Your Committee, through its chairman and membership, has during the year represented our industry on two Corrosion Symposia which were sponsored by the American Petroleum Institute; also there has been cooperation with Committee A-5 of the American Society for Testing Materials and Subcommittee E of Technical Committee 3 on Cast Iron Pipe Specifications, which committee is sponsored by the American Water Works Association and other associations.

Chiefly, however, your committee has carried forward its initial work with the U. S. Bureau of Standards on soil corrosion investigations, and a report by the Bureau, known as the Second Progress Report, has been published as Preprint 27-10, by Kirk H. Logan, a member of your A. F. A. Committee, who has active charge of the work at the Bureau of Standards in Washington.

From the net findings of the Petroleum Institute and others, estimated annual losses ranging from $100,000,000 to $500,000,000 accrue on buried steel pipe lines. Artificial coatings seem to have proved inadequate as a means of stopping these tremendous losses, which are said to be on the increase rather than decrease. Experience has shown that foundry products such as cast iron, malleable iron, cast steel and certain non-ferrous articles are much more resistant to soil corrosion than rolled steel or iron, and your committee is in full cooperation with the various interested bodies who are at present working for more complete knowledge of this subject.

Committee on International Relationships

H. C. Estep: Since the International Foundrymen's Congress in Detroit, your Committee on International Relations has been concerned with the negotiations which have been going forward all through the winter with European foundrymen's organizations looking toward the establishment of a definite program for the future.

It is a pleasure to report that such a program has now been arranged and unanimously agreed to by all of the European foundrymen's organizations. This program contemplates holding future international foundrymen's congresses as follows: 1929—Great Britain; 1932—Germany; 1935—France; 1938—United States. The European foundrymen's organizations have agreed that the International congresses should be confined to the four countries listed above and that these affairs should take place at intervals of three years.

The French, Belgian, British, German, Spanish, Dutch, Swedish, Czecho-Slovak, and other European foundrymen's organizations have joined in forming the Foundrymen's International Committee for the purpose of acting in an advisory capacity in organizing future international foundrymen's congresses.

Your committee recommends that the American Foundrymen's Association, which has been informally affiliated with this committee, now take steps to join this advisory committee in a formal manner.

The Institute of British Foundrymen has announced that it is proposed to hold the Third International Foundrymen's Congress in London, May 28 to June 1, 1929. Your committee hopes these dates may be satisfactory and that in due course efforts will be made to organize a large and representative delegation from the United States for this congress.

Committee on Apprentice Training

H. A. Frommelt: The work of the Committee on Training of Apprentices has been, of necessity, largely of a promotional nature. Using the annual convention session as a sort of clearing house of information on apprenticeship progress, development and evolution and then disseminating the cream of this information

through the regular publicity channels of the American Foundrymen's Association, it was considered possible to fulfill the objective of this Association.

Specifically, and considering the present status of foundry apprenticeship throughout the country, this task has largely revolved around the problem of presenting informative and inspirational reports of actual and successful foundry apprenticeship programs. The foundry industry today needs largely to recognize that apprenticeship is not only a necessity but a possibility. Nothing succeeds like success. In this matter also it was felt that the presentation of successful and going apprenticeship programs, operating in various parts of the country, under various and varying conditions, would do more to "sell the idea of apprenticeship" than any other one thing.

With this in mind, the Committee on Training of Apprentices has set itself up, largely, to act as a clearing house of information and a distributor of the better and best that it could gather.

The present apprentice training session is an exemplification of the working out of this fundamental idea. Since the Detroit convention, the committee has been active in gathering reports of successful and going foundry apprenticeships, which could be presented in an informative and inspirational manner, suitable to the conduct of our session.

Questionnaires were sent out to the industry through the regular channels, which sought to discover the outstanding difficulties individual organizations have experienced in developing apprenticeship. The outstanding difficulties were then enumerated, basing this upon the answers to the questionnaire, and it was requested that the report of actual foundry apprenticeships be built around answers to these difficulties.

Furthering the idea of promoting apprenticeship, the Apprentice Training Committee arranged for foundry apprentice contests, to be conducted under rules and regulations laid down by this committee. For three years such contests have now been held. And evidence of that, gentlemen, is just beneath us on the floor below. On a large table there you will find arranged castings that have been sent from four or five different centers in this

country, representing the efforts of apprentices working on castings made according to rule and judged by men who understand the foundry business. From all reports, these contests have done much to promote an interest in the idea of foundry training.

Considerable effort has been expended in laboring over a suggestion that the American Foundrymen's Association establish scholarships for young men choosing the foundry industry as the scene of their life work. Thus far no policy has been arrived at concerning the establishment or the conduct of such scholarships. However, here again, the idea of apprenticeship and foundry training has been pushed forward another step.

The future work of the Committee on Training of Apprentices will revolve largely around the following activities:

1. Increasing the usefulness of the annual session as a clearing house and distributor of apprentice training information.

2. Carrying on the work of promotion through the various foundrymen's locals throughout the year.

3. Establishing the A. F. A. more fully and completely as a permanent source of information, data, and instructional material regarding training plans, programs, methods and activities.

The Committee on Training of Apprentices, while keeping in mind the purely promotional nature of the work involved in its activities, is determined to increase the scope of its activities and usefulness along the lines just discussed. It is hoped that in this manner the American Foundrymen's Association may continue in its capacity of successfully promoting better training methods, so essential in the foundry industry in America today.

May I say informally that the National Industrial Conference Board has estimated recently through a survey that some one million apprentices should be in training in our basic industries in this country. Perhaps only one per cent of this number should be in the foundry, it is anybody's guess, but let us set it at from 10,000 to 15,000. At the present time I dare say there are less than 1,000. You can see the objective that we have ahead of us and in presenting to you people, coming from various parts of the country, the actual training programs in various foundries, not many at the present time, we hope that we will prove to you one thing, that foundry apprenticeship is a possibility, that it is

an actuality, and that it will set out to do the thing that a training program should do, and therefore, and finally, that we will within a reasonable time reach the goal of 10,000 or 15,000 apprentices in the foundry industry in this country.

Joint Committee on Molding Sand Research

B. D. Fuller: The approximately sixty gentlemen comprising this committee are all active business men engaged in their duties in the business world and they have been giving their time unstintingly to this. For further details of what has been accomplished lately I would recommend that you attend the sand sessions tomorrow, tomorrow morning and tomorrow afternoon, where the details of what they have been doing can be learned. But I do wish to preface my remarks by saying that your committee is making real progress.

The work of the Subcommittees has continued actively during the past year, and while some activities have been closed, others are still in the process of development.

The Joint Committee has had advanced to the position of standards the previous tentative standard methods:

(a) Fineness test.
(b) Permeability test.
(c) Chemical analysis.
(d) Sampling.

Sub-subcommittees of the Testing Committee are investigating more simple and more practical test methods for:

(a) Strength tests.
(b) Core tests.
(c) Refractoriness tests.

The Grading Subcommittee has had approved tentative standard grading classifications for:

(a) Grain fineness.
(b) Clay content.

Other grading factors are being considered for standardization and such factors are: grain size distribution, grain shape, and refractoriness.

The Geological Survey Subcommittee has practically completed its survey of the foundry sand resources.

The Subcommittee on Conservation and Reclamation is investigating clays for rebonding strength.

Now, that is said in a very few words but their work has been very extensive and they have accomplished a great deal. Three hundred and thirty pages of papers and committee reports were printed in the 1926 Transactions, thus indicating to some extent the activities being shown in the work on foundry sands.

COMMITTEE ON FOUNDRY COSTS

A. E. HAGEBOECK: We agree and talk and discuss a lot about sand, core oils, all the other whatnots that the American Foundrymen's Association is trying to do, and I say, what could they do, how could they keep your interest, if they didn't reduce your costs? Now, that is the mission of the committee which I happen to be identified with, and on that committee we think we have the men in the industry, in its four branches, who know most about foundry costs. On the steel end we have W. J. Corbett of the Steel Founders' Society of America; on malleable we have R. E. Belt; on the gray iron we have E. T. Runge, and on the non-ferrous we have J. H. Harris.

We had a meeting yesterday, and the result of that meeting was that at the present time we feel that our committee has made very definite progress in its educational work, in calling the attention of the foundrymen to the need of knowing more accurately their costs. We would like to call your attention to the fact that of about 150 steel foundries, about 50 per cent of them are now figuring their costs by the method recommended by the Steel Founders' Society. Now, it is the position of the American Foundrymen's Association committee that we should encourage the use of that method as a standard in the steel industry. We have practically the same condition in the malleable industry. We have 50 per cent of the malleable foundries using the method has made any real progress in the gray iron industry.

The situation in the gray iron field is not as bad as it is generally thought. We find about 200 gray iron foundries that

are using one method. That method seems to be the only one that has made any real progress in the gray iron industry.

In the non-ferrous industry we are very sorry to report that there has been no concentrated effort along any standardization lines that we are able to find out. Therefore, we would like to suggest to you that our policy and our program is educational first, that we would like to recommend to the steel foundry men that they go along with the one method that has been adopted and used successfully by the steel foundries; that the malleable men do the same as related to the system put out by the Malleable Iron Research Institute. For the gray iron we find now about 11 local associations of gray iron foundries, local groups as they are called. Now, from an A. F. A. standpoint we suggest to those local groups to get together and standardize their method and then the A. F. A. committee will be very glad to take that method that they recommend and see if we cannot help them make it standard in their industry.

The non-ferrous industry we hope in another twelve months to be able to make more of a progress report on.

Committee on Gray Iron Castings

J. L. Jones: At the time that the chairmanship of the Committee was assumed, the problem of the influence of additions of iron and steel scrap to the blast furnace was mentioned as a desirable subject for investigation. For quite a period it seemed impossible to make much progress with this subject. Finally, through the efforts of R. S. MacPherran, a member of the committee, we learned that the Iroquois and Federal Furnaces of Chicago were willing to do some work on this question and that Dr. Richard S. McCaffrey, Professor of Metallurgy, University of Wisconsin, would be willing to supervise the work.

This plan, however, did not bear any fruit. The general belief seemed to be that blast furnace men were not in sympathy with any such series of experiments. Subsequently, E. J. Lowry, a member of the Committee on Gray Iron Castings, informed us that the Susquehanna Furnace of Buffalo, N. Y., had expressed a willingness to run a series of tests in the above furnace in cooperation with the A. F. A. This seemed very promising, as

H. Bassert & Co., Hickman, Williams & Co., and Messrs. Rogers-Brown & Crocker Bros., prominent firms in the design of blast furnaces and in the manufacture of pig iron, seemed to be very interested. Mr. Lowry, however, has been unable to make any progress with these people.

Finally, Mr. MacPherran has had some correspondence with Mr. Fieldner of the Bureau of Mines in regard to the government doing some work on this question at the experimental blast furnace of the Bureau of Mines, at Minneapolis, Minn. The difficulty in carrying out this proposition seemed to lie mainly in the large sum of money required to operate even this small blast furnace. However, the subject has been pushed wherever possible, a paper having been read by W. E. McKee at the Pittsburgh meeting of the A. I. M. M. E., October 5, 1926, on "The Use of Iron and Steel Scrap in the Blast Furnace." This paper and the discussion that followed were of some value and at a similar meeting of the A. I. M. M. E. in New York in 1927 the subject was given considerable attention by the Board of Directors of the A. I. M. M. E. and a special session was arranged to discuss the subject.

Due to this agitation and the personal influence of Dr. Richard Moldenke, two prominent consumers of pig iron made arrangements with certain furnaces to run all-ore pig mixtures for them specially, they paying the furnace a sufficient premium to reimburse them for the lost tonnage profits. Mr. R. H. Sweetser of the American Rolling Mill Company, and who was Chairman of the discussion at New York City before the A. I. M. M. E. when the subject of Adding Iron and Steel Scrap to the Blast Furnace was introduced, has, as you are aware, been secured as Chairman of the proposed discussion on this subject which is to be held at this meeting of the American Foundrymen's Association.

Your Chairman submitted to Technical Secretary R. E. Kennedy an Acknowledgment Paper for the French Foundrymen's Association on the subject of "The Effect on Pig Iron of the Addition of Iron and Steel Scrap to the Blast Furnace."

The Finance Committee of the American Foundrymen's Association has approved the proposition of the Committee on Gray Iron Castings to use the Rogers-Brown & Crocker Bros.

fund, which now amounts to about $560.00, in the preparation of a bibliography on cast iron. This project is now being carried on actively, under the direction of J. W. Bolton.

Active work is also being done by the members of the committee, in cooperation with the Bureau of Standards, on measuring the temperatures of molten cast iron under varying conditions, and some valuable information has already been secured.

Some cooperative work on the subject of specific heat of cast iron has been recently under discussion with the Bureau of Standards. Some tentative plans have been discussed with the Bureau of Standards in regard to some work on this subject.

International Test Bar

Some tentative methods of work have been discussed and considerable correspondence has been carried on with the members of the Committee on an International Test Bar in various European countries, including England, France, Belgium, Holland, Italy, Czecho-Slovakia, Spain, Switzerland, and Germany. No essential progress has been made, but an active interest has been shown by the various "overseas" members of this Committee in the subject, and in other subjects of mutual interest.

Committee A-3 of the A. S. T. M.

As the membership of the A. F. A. Committee on Gray Iron Castings and the Committee A-3 of the A. S. T. M. is very similar, an active interest is being taken by the membership of both societies in testing questions of mutual interest, such as fatigue tests, correlation of test bar to castings, etc.

We are compiling data on these questions, which are of very considerable practical interest to all foundrymen, and we hope to be able to publish papers on these various subjects in the near future.

Committee on Heat Treatment of Ferrous Metals

A. W. Lorenz: The Committee on Heat Treatment of Ferrous Metals was organized some years ago primarily to work

jointly with a subcommittee of A. S. T. M. Committee A-4 in the formulation of a practice for the heat treatment of steel castings. This work is now embodied in the A. S. T. M. Standard Recommended Practice for the Heat Treatment of Carbon Steel Castings, Serial Designation A-27-24.

With the adoption of these Specifications by the A. S. T. M., the major task of our Committee may be considered to have been completed. It is regarded as part of our work, however, to keep in touch with the general activities of other societies in so far as they may relate to the treatement of ferous castings, and especially with Committee A-4 of the A. S. T. M.

The latter committee is now sponsoring an effort to develop suitable definitions for terms involved in heat treatment. While your Committee on Heat Treatment is not actively represented in this work, certain phases of the same will probably require our attention during the coming year. Aside from this matter, nothing definite lies before our Committee at the present time.

Committee on Foundry Refractories

C. N. Ring: The first work of this committee was in conjunction with the Department of Commerce. A meeting was held in Washington, D. C., on May 21, 1923, where an attempt was made to initiate a program for the simplification of refractory shapes and sizes. Due to small attendance at this meeting and subsequent lack of interest by both consumers and producers, nothing was accomplished and the work of this committee lagged until the annual convention of the American Foundrymen's Association in Milwaukee in 1924.

At this time permission was obtained from the Board of Directors to attempt the formation of a Joint Committee on Refractories under the sponsorship of the American Ceramic Society, such joint committee to take over the activities of many committees on refractories representing various societies and organizations. This Joint Committee was successfully formed during the annual convention of the Ceramic Society at Columbus, Ohio, in February, 1925. Mr. L. C. Hewitt of the Lacledе-Christy Clay Products Company, was made chairman. From that

time on all of our committee activities were merged in that of the Joint Committee.

The first meeting of the Joint Committee was held in Pittsburgh on September 14, 1925. Since that time it has been very active in working out methods of testing refractories, drafting specifications, and making a survey of refractory requirements of the foundry industry. At present an attempt is being made to revive interest in the simplification of foundry refractories. A subcommittee is working to interest consumers and producers.

At yesterday's meeting of the Joint Committee there was unanimously adopted a tentative draft of standards on shapes and sizes for the malleable foundry industry. The American Foundrymen's Association, the Refractories Institute, and the A. S. T. M. will be formally requested to lend support in giving publicity to this tentative list of standards, and after a certain amount of publicity has been obtained, the Department of Commerce will then be called upon to cooperate with the Joint Committee in promulgating these as active standards.

A. F. A. Representative on Joint Committee to Consider the Placing of Weights of Castings on Blue Prints

A. B. Root, Jr.: For those who were not present at the meeting last year, I will read the report as I prepared it for our records, although it does not show a very much different situation than existed at that time.

A meeting of this general committee was held in Washington under the direction of the Chamber of Commerce for organization and discussion of the subject at hand. As a result of action taken at this meeting, questionnaires were sent out by the Department of Commerce to ascertain the attitude of interested manufacturers toward this project.

The results of this questionnaire were discussed at a further meeting of the Committee on December 31, 1926. Analysis of the replies indicated a large majority in favor of the movement but there was a very strong minority, consisting of many of the most influential and important companies, who were quite emphatically opposed to it.

With this minority opposition, it did not seem advisable to proceed with the original plan. A special committee was then appointed to draw up and submit a modified form of inquiry and quotation embodying the request that approximate weights be incorporated thereon. This subcommittee held a meeting on December 7, 1926, and prepared the information for such a form. This form was then distributed to certain association members and replies received indicated rather strenuous opposition to the substitute plan, that it did not accomplish the original ideas and should not be executed therefor.

As a result of this apparent deadlock between the members of the committee itself, no further action has been taken, and Mr. Hunter, the General Chairman of this committee, has the matter still under consideration as to what further action, if any, can be taken to accomplish the desired results. This association went on record last year as very emphatically favoring the plan for the placing of the weights of castings on blue prints that were submitted for quotation, and as your representative on that committee, I transmitted that information to them. I feel that further consideration will be given it and undoubtedly within another year some definite action either one way or the other will be taken.

Committee on Steel Castings

A. H. Jameson: When your Committee began its work this year, it found the specifications for steel castings giving general satisfaction to both the producer and consumer, and so recently framed as to reflect pretty accurately the standard practice of progressive foundries. The specifications for railroad castings, after several years' work of separate and of joint committees, and in spite of features objectionable to some, had been accepted by both foundries and railroads and were in general use. The only unfinished work then seemed to be the specifications for steel castings for valves and fittings for high temperature service, offered tentatively and still on trial.

During the year there have been many meetings of committees and of committees within committees, at all of which your representatives have been in attendance. There have been many compromises and at the last an impasse, for in recent meetings of

The American Society for Testing Materials Committees it has been voted to permit only the use of open hearth and electric steel castings, thereby excluding the converter and crucible, and to impose chemical limits in addition to physical requirements, this in spite of protests filed by all the foundry organizations of national scope, by many of sectional character, and by numerous influential foundries independently, together representing practically the entire organized foundry industry of the country.

So we are now in the very midst of a fight for a principle which affects you all and we ask your support and counsel.

Foundry Costs

CHAIRMAN A. E. HAGEBOECK: Gathered here to discuss the subject of foundry costs, and coming from various parts of the country, we should first get acquainted. We have representatives here from the following groups: The Ohio State Foundrymen's Association, The Twin City Foundrymen's Association, The Chicago Foundrymen's Club, The Pittsburgh Foundrymen's Association, The Newark Association, The Quad Cities Foundrymen's Association, The New England Foundrymen's Association, and The Tri-State Foundrymen's Association.

Chairman Hageboeck then called on the various representatives to rise, and to give their names and firm connections.

CHAIRMAN A. E. HAGEBOECK: We reported this morning at the opening session that the one thing that our committee feels it should do is continue its educational program on matters of cost. Without doubt no progress made can be measured any better than its effect on costs. But if you haven't a background to start from in the making of any changes or improvements, it is hard to really measure, so far as the manager is concerned, whether you are accomplishing anything. Therefore, we consider the knowledge of costs is vital.

The malleable iron field is fairly well taken care of in the matter of a standard cost system. About 50 per cent of the malleable iron foundries are now working with a system that has been used for a number of years, namely, the system advocated by the American Malleable Iron Institute. The American Foundrymen's Association Cost Committee recommends to those other malleable foundries not using it to investigate and see if they cannot use it to advantage. By this recommendation I believe is where our A. F. A. committee can be of service to the malleable branch. The same condition applies to the steel branch.

The Steel Founders' Society of America has a method that has been used a number of years. It is giving very good results

and they are anxious to get, like the malleable fellows, the other 50 per cent lined up and using this method in all steel foundries.

The non-ferrous branch of our industry evidently has made scarcely any progress towards a unified system of costs for their industry. We have a sub-committee on that branch now and it has promised to have something to report in the way of some kind of program for next year.

The discussion today will be on the matter of handling costs by groups as applied largely to the gray iron foundries. Those of us who have studied the problem seem to think that the best way to make the greatest progress is by getting foundrymen in one certain locality to think of their costs as a group interest in that locality. We have 12 groups of gray iron foundrymen who are studying their costs as a group.

Now as an introductory talk to start the discussion this afternoon, we have a man who has probably had as much experience as anyone in handling just this thing. There are a number of foundries in and around Newark, New Jersey, that have been working on costs as a group. And I take great pleasure in introducing a man, J. L. Carter of the Barlow Foundry, who is well qualified to talk on that subject, his subject being, "A Uniform Cost System for a Local Group."

A Uniform Cost System for a Local Group

By J. L. Carter,* Newark, New Jersey

In Newark, N. J., we have a group, consisting of 12 foundries, which has been operating on a uniform cost system for over four years. So you can see our undertaking is no experiment, it is a proposition that has been tried out. I can very honestly say every member of the group is today enthusiastic about the results we have obtained. We have had a foundrymen's association in Newark for a great many years, and, like a good many other foundrymen's associations, had been talking costs. We had been preaching costs for a long time, but until 1923 we never got down to brass tacks, so the result was about nil.

In 1923 one of our largest foundries had an unfortunate experience and it was a very good thing it did. It was making about 50 tons of work per month for a customer. It had been making it for about 20 years, and it was getting 6½ cents a pound for it. Another local foundry came along and got the order. This first foundryman came to see me, he was wild about it. He knew just what the work cost and knew he wasn't making much on it, so the other foundry must be all wrong. And he said if that sort of thing was going to continue he could cut prices, too, and he could stand the gaff as long as anybody else.

I tried to calm him down and after considerable discussion managed to convert his indignation into a real desire to do something constructive about it. So two of us called in two other local foundrymen and formed a uniform cost system group. We were fortunate in getting a man who had been a cost accountant for one of the local foundries. They had shut down their foundry and he was out of a job. He had been with this concern when Knoeppel introduced a cost system in this plant and had a very good training under him. He had had just enough experi-

*Barlow Foundry, Inc.

ence to appreciate the good points and some of the weaknesses of such a system.

We four went out and got two other foundries to join us and we jointly hired this man to install and operate a uniform cost system in our group. Naturally, we had our troubles getting started, as anybody would have, and all the foundrymen were not thoroughly sold on the idea at first. Some were skeptical and some thought it was just a gamble. Others went along just to be good fellows. In fact, one man continued his old system for a year alongside the new one. He thought his old system was better.

Also we had some trouble with the individual members of the foundries, the cost clerk or the superintendent would be antagonistic. But we gradually lined them up. But we didn't start, gentlemen, with a complete set-up; we worked it out as we went along. We frequently had meetings with our cost accountant and we adapted his ideas to meet what we thought were our individual needs.

There were some of us who were very much convinced the idea would work. We kept on because of the hope that within a year every executive would be thoroughly and completely sold on the idea. We started, soon after the installation of the system, to get out comparative reports. A good many of you men have seen these comparative reports in your own group. If there are any of you who have never seen a comparative report, I want to say it is one of the most valuable things any foundry executive can possibly have to give him information on which to run his business. These comparative reports show various items of cost, such as cost per pound, direct and indirect labor per pound, overhead, cost of melt, office salaries per ton, fixed charges per ton, etc. Any foundry executive looking over this cost report will see just how his figures compare with the figures of other foundries in his own district, and if you find your costs high in any particular respect, you know right where to concentrate your efforts. It is of great value in pointing out the weaknesses and it is also of great value in convincing your superintendent or foreman that he is high.

I believe you all know the attitude of the ordinary superintendent. It is pretty hard to tell him he is not the most efficient operating head in the country. He has all sorts of alibis. He says, "We are not doing the same class of work as those other fellows. Our cost would naturally be higher than So and So's." But if you can show him a comparative report and show him that his cleaning costs are higher than the average, then you can make some impression on him. And if you have a local cost man, such as we have, who is in touch with the operating conditions, you can pretty soon convince your superintendent he is high. And when you convince him of that, he is going to go after that particular item of cost. You can tell him that he has either got to cut that item of cost or you are going to get somebody who can.

I personally know of a great many very big savings that have been effected in our group, which would not have been effected if we hadn't had this uniform cost system. I know since we have had this uniform cost system in our foundry we have cut our cost down to where we are saving about $5,000 a year in the one item of cleaning cost. And we did that largely because we were able to convince the superintendent he was high and we got him working hard on the proposition.

In another foundry we found their bench jobbing division was showing a loss. And by careful analysis and by studying the matter very thoroughly they changed that loss into a profit. They are saving on that item what would amount to about $5,000 a year.

In another foundry we found their overhead on floor work was ahead of the others. We analyzed their situation and found how many men they were using in proportion to the number of molders. We found they were able to cut the number down to ten men, which represented a saving of about $12,000 a year. And I am quite positive none of these savings would have been effected had they not had the uniform cost system.

In telling you of the advantages of the uniform cost system, I want you to remember that I am not an accountant and am not trying to sell you any system or telling you what advantages you will derive if you put in my system. I am telling you the actual experience of a group of foundries after trying a method out for

four years. And if you are still skeptical, I have some letters here from the foundries in our group which I will be very glad to show you after the meeting.

The first result of the uniform cost system is that the foundries in the group learn how to figure their costs accurately. Of course, if one of the foundries didn't have any cost system before, you can see that is a great advantage to the whole district, more so than if you had a system before. But if you did have a system before, you can find that that can be improved upon when you get into the group idea. The man who has had experience in a number of foundries can usually improve on your system, I don't care how good it is. In the letters from the members of our group, I think everyone admitted, although they originally thought they had a pretty good system, that they eventually were convinced our group system was better.

The first thing you teach the foundrymen in your group is how to figure their costs accurately. It eliminates a lot of ignorant competition, you don't have a lot of price cutting, and it stabilizes the market. Of course, it doesn't cut out of town competition, it doesn't solve that problem, but it helps. It is a step in the right direction. It made a big difference in our local situation, I know. The members of the cost group are not cutting each others' throats and pirating the way they used to.

I have spoken to you already about the advantages from the comparative cost statements. They are perfectly remarkable. You will be surprised, if you have never tried it out, to find what an advantage it is to you as an executive to be able to check up your costs with other foundries right in the district. It is the biggest aid you can think of to any executive to be able to run his foundry correctly.

Our method in Newark is a little different from some of the other groups mentioned by Chairman Hageboeck. We have one man who gives his full time to our group. He is available if we have any trouble; if the cost clerk has any trouble, all he has to do is call up the cost consultant and he comes over and straightens the clerk out. Furthermore, if you find your costs are high, just call in the consultant. He is developing into almost an efficiency engineer for the group. His services are exceedingly valuable.

In short, we are fortunate in having such a good man, one who will not divulge any private or personal information, and we are quite enthusiastic about the way he has handled the job.

Another big advantage you get from this group method is the tremendously better feeling among the foundries. When you have a group of 10 or 12 foundry managers meeting together and discussing their costs, comparing them, and in general exchanging their experiences, you will be surprised to find what a different feeling comes to exist in the community. Competition is much more friendly, which is a very important point.

Now I don't intend to go very deeply into the system itself. I didn't come here to boost the Newark Foundrymen's system. I came here to urge you to start local groups wherever you are. Any system is better than no system.

If you are going to start a uniform cost group, you must have a simple system to start with. And you should have a system that is capable of expansion. If you go to a man who hasn't any cost system and ask him to put an extensive system in it isn't the most simple thing and he is sure to get disgusted with it pretty soon and throw it out. But if he will start with a simple system, he will gradually learn and understand it and will make use of it. And then you will see how he will come back for more detail. When he once gets the idea of how he can use it for true information in increasing his profits, he will want a lot more detail.

We can expand our system so it will give you full information; in fact, it will give you practically anything you want.

Any foundry which comes into our group can have just the bare skeleton of a system, the simplest possible form and so simple it won't frighten anybody, and it doesn't require any extra clerks. And then they can elaborate on that as much as they wish. Naturally, when you go into customer's cost, you have to figure on a little extra clerical labor. But that is entirely up to you.

I will just outline the main features of our system. We carry, of course, core cost and a separate overhead on core cost direct. We carry cleaning cost, cleaning and shipping cost, and all the rest of the overhead is carried as a percentage of the direct molding labor.

There is one item which I personally feel is rather important in which our method is different from some of the methods in use in some of these other groups, and that is that we found it very important to divide the molding department into at least two divisions, the floor work and the bench work. It is quite a common figure to have the overhead on our bench work run as low as 70 per cent, and to have our overhead on our floor work run as high as 150 per cent. That was one of the striking things shown when we started this system. We found we were all doing our floor work at about cost or that we were losing money. Naturally, we were all very much interested and all started to get busy, and we either increased the price or got the cost down until some very remarkable results were shown.

If you want to start a system in your town, just go to your best friend among the foundries and talk it over with him. Get him sold on the idea and then call in a couple of more foundries, and then get them sold on the idea. You can start with four foundries. Then get a hold of some cost accountant. Call in some cost man and get a system working and you will be surprised at the advantages that can come to you. And later on you will be able to get in many foundries. You can ask the A. F. A. Cost Committee here for help and I am sure they will be glad to give you any assistance they can.

I wish I was able to express myself better so I could really put across to you men the importance and the necessity for some work of this kind. You all know the general conditions in the foundry business, especially in the gray iron foundries. The gray iron foundry industry is getting a very small return on its investment. It is not considered a very good risk by the banks. In general, there are many castings being sold at ridiculously small profits, some at cost, and some below cost.

The latest figures I have as to capacity operation of gray iron foundries show that they are running at about 55 per cent. All the foundries, of course, try to run at 100 per cent, and when you have a condition like that, you are bound to have disorganization.

You know the way the thing goes, the manufacturing plant that has a foundry as a subordinate part of its business gets

slack in its line, and then it takes business at cost or below. The foundry is only a side issue with them. Such organizations do not care whether they make a profit in the foundry or not, they will take the business at cost or at a loss, to take care of their foundry overhead. The foolish jobbing foundryman decides to meet their prices in order to hold on to his customers. And what is the intelligent jobbing foundryman going to do about it? Usually he can't wait for his foolish competitor to go out of business, for he himself is liable to go to the poorhouse in the meantime. And when the first fool does go out of business, some other fool will buy him out, and maybe he will be a worse fool than the old one, or maybe some new foundry will start up.

You have to realize you can't solve this problem yourself. You can't set the prices at which you sell your castings, they are going to be set by some of your competitors. And sometimes they are going to be set by comjetitors five hundred miles away. But the majority of prices are going to be set by competitors in your own immediate vicinity. If one or two foundries in your own town don't know their costs, they can thoroughly disorganize your casting market. And if one or two foundries in your own town don't know their casting cost they will make it impossible for you to make a fair return on your money, no matter how efficient they are.

Some people will say that there is only one way to beat the game and that is to produce castings cheaper than your competitor. That is very true, you have to get your cost down or you will be out of the running. By all means get it as low as you can, put in the proper equipment, put in molding machines, put in a conveyor system, put in sand handling apparatus, if you are big enough, if not, if you have a small plant, don't put it in, but keep your cost down as low as you can.

And when you get through what have you? You probably may be able to make 6 per cent on your money. But why take the trouble to run a foundry to make 6 per cent on your money, why not put your money in some savings and get your 6 per cent? Any man who can't go out in the market and buy securities and make 6 per cent is not clever enough to run a foundry and make more than 6 per cent today.

So that under these circumstances I don't see how any intelgent foundryman can escape the conclusion that one of the most important fundamental steps he can take is to start some movement which will help educate his competitors to know their costs and bring about better cooperation among the foundries in his own town.

I have come here today just to tell you that I believe the adoption of a uniform cost system in a local group of foundries in your own town is a most effective and probably the most far-reaching step you can take to remedy the conditions in your locality and in your own foundries.

Discussion

Member: Mr. Carter, I believe you stated you had two molding subdivisions, the bench and the floor. Do you think that covers everything?

J. L. Carter: In our group of 12 foundries we have every conceivable number of divisions; some foundries only have two and some have six. It is entirely optional how many divisions you carry in your foundry. In our own foundry I think we have five. Any foundry which has become familiar with the cost system will probably have more than two, especially if they have jolt machines or even squeezer machines as distinguished from bench work.

It is important in starting a uniform system to start with something very simple and then after the foundry learns how to use the system you can extend it so they can get as much detail as they want. It is perfectly possible to have a cost system that is as simple or as elaborate as you wish and still have the fundamental basis exactly the same.

Chairman A. E. Hageboeck: That point is very well taken. Many foundries have different classes of work in the same foundry and care should be exercised so the expenses are properly distributed.

Member: Mr. Carter mentioned about the superintendent being hard to convince. Which was the hardest, the sales force or the superintendent?

J. L. Carter: Well, we had the sales a little bit more closely under our own personal control, because another man and myself do most of the selling. We didn't have much of a job in that respect. It is very difficult, of course, to control the sales department. I don't think your cost system is so effective in convincing your sales department as it is your shop

man. You have to convince your sales department with your own personal arguments.

MR. GILL: I don't think the sales department has anything to do with it. If the company sees fit to sell at a loss, it is up to the company. The company should know what they are doing after they have once got the cost figured.

CHAIRMAN A. E. HAGEBOECK: Whether you add a profit is immaterial, once you have your cost. But the cost system is always more effective with your foreman and superintendent, there isn't any question about that. He is watching it all the time. I know at first when Mr. Runge put in our system, he called attention to the fact that our expense labor was high in our core department. I had been trying for six months to get some action on it and couldn't, and the consultant came along and put it up to the superintendent from a different angle and got results.

MEMBER: I would like to ask Mr. Carter just how he arrives at the difference between the overhead on the bench and the overhead on the floor work?

J. L. CARTER: Well, if you want to get the difference between the overhead on your bench and on your floor, you have to definitely subdivide your indirect labor. It is a question of getting the proper time. You have to get the time from your laborers and charge it either to the bench department or the floor department, allocate your purchases and other expenses to those two departments. It is a very simple thing to do and it doesn't take a great deal of work once you get it rolling.

CHAIRMAN A. E. HAGEBOECK: Mr. Carter, isn't it a fact when you said overhead you had primarily in mind indirect or expense labor?

J. L. CARTER: Yes.

A. P. GRIMM: Mr. Chairman, I don't quite agree with Mr. Carter. I am a member of the Newark group. I haven't yet joined that cost group, but I hope to within a short time. But I don't think you can figure the cost on the heavy and light work without giving consideration to the amount of investment in that particular department. In your heavy work you possibly have an investment in heavy cranes and for the men who are operating them. But very usually the tonnage on those particular floors offsets the production you would get under the bench. I know in my own plant on some bench work I will have a very low overhead and then I will have some which will run considerably higher. And then under the crane work made on molding machines, I have had some which, if I had given the investment of the molding machine any consideration, the cost would have been considerably greater.

Now this group idea is the thing I have been talking to Mr. Carter about right along. It is all right locally, but I find it isn't far-reaching

enough. If you don't have a group that is working under the same idea within a radius of 50 or 100 miles, those other fellows are eventually going to have all the work and you aren't going to have anything. So that I don't think it is so much a uniform cost as it is a uniform basis of overhead. That is my opinion about it.

J. L. CARTER: Don't make any mistakes about the words "uniform cost." It isn't uniform cost, it is uniform cost system. That doesn't mean at all that the cost in all our foundries is the same, for it isn't. It varies considerably. It is simply that we figure our costs the same way. If one foundry in our group is more efficient than the other on a particular job, their cost will be lower, but they will figure it the same way.

Now about the fixed charges that Mr. Grimm mentions; the fixed charges, of course, are apportioned to the different departments according to the amount of equipment in that department. So I think that takes care of that point.

Now about this out-of-town competition. That is a very important point. It is an argument a lot of foundries bring up who don't want to join your group. Gentlemen, you cannot control foundries that are 500 miles away. It is no use trying to do it directly. But you can do something to help the conditions in your own town and if you eliminate half the ignorant competition you run up against, you are that much better off.

Now this uniform cost system has helped us to some extent to reduce our costs, because we have been able to find weak points and remedy them. At least, we certainly don't find our costs any higher. There is no price agreement connected with this whatever. It is purely an educational proposition. The only way we can get anywhere is to start a group in our own locality and hope by doing a little missionary work the people in the next locality will soon start one, and the ones over here will start another one. Philadelphia now has started a group. They are very near us. New England, up around Boston, has started activity on the question. I don't know how far along they have gotten. But eventually, if we can keep on pushing this group idea, these different groups will be springing up all over the country, as they have been within the last five years. And when it gets general enough it will have its effect on your out-of-town competition, which is the bugbear of every local foundry industry.

CHAIRMAN A. E. HAGEBOECK: I would like to ask about that New England group. I heard a year ago they were forming a group. Has anyone here any information about what progress they have made?

MR. ROBINSON: The New England people for many years have been talking the matter over and, as Mr. Carter intimated at the start of his discussion, they are in the same position now as 25 years ago. A situation during the past two years has arisen where they have tried to get a number of people to combine into a group. But I think I am safe in saying that nothing further has been done other than just discuss it. But it does

seem they have now reached the stage where they have decided that a certain sum of money be paid quarterly to obtain the services of someone to get them started in the right direction. However, other than that I don't believe they have formulated a group as yet.

F. A. KALES: In our group out on the Pacific Coast we are taking in four groups, the gray iron, the steel, the brass, and aluminum, and we assumed that the fundamental principles of this cost system Mr. Carter was talking about could be applied to any one of those different branches of the industry. We thought we could set up the form and that every branch of the industry would know what the metal was costing, such as pig iron, or aluminum, or whatever it was. Is that not possible, Mr. Carter?

CHAIRMAN A. E. HAGEBOECK: I would like to answer that this way, by saying that our Cost Committee as a committee of the American Foundrymen's Association recognizes in the steel branch of the industry the cost method that has been evolved by the Steel Founders' Society of America, whose head office is at Pittsburgh.

I would say, as an individual, that your steel branch would be better off conforming to the method that is used by other steel foundries in the United States. And when it comes to your malleable problem, I don't think this system that Mr. Carter is using would be recommended by him for use in a malleable foundry.

MR. CARTER: Not while the Malleable Iron Research Institute is going.

MR. KALES: Our problem is this. We are rather far removed from the foundry centers of the United States, inasmuch as we have two large steel foundries and probably three who are not paying any attention to the other fellows. They have been going along that way for a number of years. And this group we are trying to form is made up of the younger fellows who are coming up in the business, who have started in the business in the last four or five years. We are trying to get the larger fellows into our group, but they are not paying much attention at the present time. However, we are hoping to get them in later on. And I was wondering if we couldn't form some sort of cost system to take in this entire group of foundries?

A. J. MORSE: I just want to say that I am another man from California. I wish to say we have organized a steel group in Los Angeles which has not been in operation very long. We have five steel foundries there. But I think it has been of great help to us.

We also had a general group of all the foundries which had been working together for between one and two years under the leadership of a cost expert, but with rather indifferent results. We, however, have much better results in our steel group through close co-operation.

It seems to me, in answer to the gentleman's inquiry, if the members of the different lines of foundry work would form their own groups and

work together as closely as they could—they have similar conditions and they are all doing a similar kind of work—that they would get better results than if they mixed up all the different lines of foundry work under one group.

I am glad to hear the Oakland people are starting along that line, because we have had some competition from the North and it's almost 500 miles away.

MR. LYND: There is one point I would like to make which I think might clear up the questions asked by the gentleman from California. The question as to what sort of metal you are dealing with, to my mind, has no effect on the cost of getting castings. In other words, your molten metal in any foundry is a distinct item of cost in itself. Whether you start at the spout or ladle, no matter what the metal is, that is one section of your cost. Beyond that the costs are almost identical. Our cost system is identical, but our molten metal is a factor in itself whether it is iron, steel, brass, or aluminum.

MR. SEEGER: I might say that I went out and tried to do a little missionary work to start a group. I went a little way and not very much further. So I would like to hear from someone in addition to Mr. Carter who has started a successful group just what the mechanical workings of the thing were. How did they go about getting it started? Everybody admitted it would be a fine thing, but still they wouldn't join when it came to a showdown. There was something which didn't quite go over. Maybe somebody can tell me how to overcome that and that would clear the thing up.

CHAIRMAN A. E. HAGEBOECK: I am going to have one of our speakers give his talk now and then if he hasn't answered the question, we will go back to it again.

The gentleman who is going to talk to us now represents a group which is rather interesting from several points of view. In the first place, there are seven foundries in and around Cincinnati, Ohio, and they are operating on a closed shop plan. They are all organized shops. And in the last seven years some of those shops have gotten down to as low as 20 per cent of capacity. But they have been able to stand the gaff and are still here. They made machine tool castings. I am going to ask Mr. Albert Wessling of the Wessling Brothers Foundry Company of Cincinnati to tell us about seven years of foundry cost accounting.

Seven Years of Foundry Cost Accounting

By A. Wessling,* Cincinnati, O.

The answer to the question as to how to form an organization of foundrymen will serve as my introduction. The jobbing foundrymen of Cincinnati, previous to the World War, were in a deplorable state. They had no use for each other whatever, because they were all trying to make a living off of the small tonnage that was to be had from the machine tool builders. These latter had learned to work one foundryman against another and being but human, some of them did not hesitate to take advantage of the situation to get ever lower prices on their castings. The results for our company during one of these years was such that I doubt whether we were really paid for our labor and materials on some of the work we did. We donated all overhead, including salaries.

In 1915 the European war began to bring business to the city and the foundries began to get busy. In 1916 the volume increased and when all the foundries got real busy, one of the older men realized that it was time for the foundrymen to get together. We were facing this condition. The demand for castings was much greater than the limited number of molders could produce. Every foundryman wanted to run his plant at full capacity, but to do so he would have to hire molders, who were working for his competitors, by offering more pay. His competitors would have to meet his offer in order to hold their men and in retaliation might try to get some of his men by similar methods. Such a procedure would soon have demoralized the whole industry and it was but necessary to call the foundrymen together and point out the danger in order to stop it.

Having brought the foundrymen together to discuss a matter in which cooperation was of great mutual advantage, it was not hard at that time to start the organization known as the "Tri-

*Wessling Bros. Foundry Company.

State Foundrymen's Association." It was given this name because one of the foundries was located in southern Indiana, four were in Kentucky and the other eleven were in Ohio in or near Cincinnati. These were all jobbing foundries employing union molders and coremakers. This association had no trouble holding its members during the prosperous years.

In 1919 one of the members called attention to the Runge system of cost accounting and the association asked Mr. Runge to come to Cincinnati and make an analysis of the foundry costs as he found them, present them to the organization and then let the members consider the matter of working together on a uniform system. This analysis showed a wide variation in the methods of figuring costs, due partly to varying conditions in the shops and partly to lack of understanding of cost accounting. Two of the foundries were adjuncts of machine shops, one was part of a structural steel plant, one was a steel foundry, two had a line of stove and range work of their own, but all did jobbing work, mostly for machine tool builders.

The member who recommended the Runge system had found it in use in a number of places while he was traveling about as a pig iron salesman previous to his entering the foundry business. His strongest recommendation was its simplicity. Mr. Runge has a system which any foundryman can understand and apply and it does not require the addition of a lot of clerks just to keep track of the time and figure the costs. He claims that in any foundry in which records are kept of the molders' time so as to be able to charge it to the individual customers, it will not be necessary to hire any additional clerical help.

When Mr. Runge came to us, some of the foundries had practically no cost system at all, while others had systems which answered their purposes fairly well. So far as we were concerned, our system was in fairly close agreement with that of Mr. Runge, and after we adopted his, it was only necessary to add a few accounts and distribute the overhead in a somewhat different manner from what we had been doing. In a short time the new system began to work quite satisfactorily and as a result the foundrymen presented a better front than they had ever shown before. They knew what their prices ought to be. Mr. Runge simply took the figures from their books, showed them what their

costs were and showed them how to estimate on new work, if necessary. He also showed them how to figure costs on any individual customer's work, so they might know exactly what they were doing on every customer's work.

During the greater part of 1920 things were fine for the foundryman, but by the end of the year the bottom seemed to have dropped out of everything. The members of our association felt that a reduction in wages comparable to the reduction in the cost of living and in the prices of castings would be proper and asked the molders for a reduction in wages. During the boom period the Iron Molders' Union had accumulated a large sum of money and the officers of the union evidently felt that this reserve might be distributed among the members to best advantage at that time in the shape of strike benefits. Accordingly the molders went out on a strike, which lasted over three months, while strikes of molders were quite general elsewhere. As every member of the union who was in good standing at that time received $7.00 per week as strike benefits as long as he was out of work, many received more money during that period than they could have earned, because of the scarcity of work. When the treasury surplus had been sufficiently reduced the men accepted a reduction in wages from $7.00 to $6.00 per day and returned to work. A year later a further reduction to $5.50 per day was made after a month's strike. By this time we had lost three members who went to the open shop plan. Since then three foundries have been closed and three others have left the organization. One of these last three dropped out as a result of two changes in ownership, while another was doing so little that expenses were reduced wherever possible. Since 1920 most of our group have been operating far below capacity. Some members have operated at 5, 8, 12 and 15 per cent of normal for months at a time and our normal means 80 per cent of full capacity. They might have been doing better than this had they been willing to accept prices offered by out-of-town competitors, but when these prices went too low, they let jobs go. And because they know their costs, our members knew when to let go.

Before the World War the foundries in Hamilton, Ohio, were our keenest competitors. The Niles Tool Works, Hooven Owens and Rentschler, and Long and Alstatter were old firms operating

their own foundries and furnishing considerable work to local jobbing foundries during periods of unusual activity. Skilled molders were numerous, and as Hamilton as a whole was a non-union town, wages were lower on the average and output per man was higher than in Cincinnati. During the boom period the Iron Molders' Union sent a man to Hamilton to induce the foundry workers there to join the union and his success in doing this was a surprise to the officials of the union as well as to others. The effect of this came to our attention about six months ago. About that time the foundries of Hamilton, Middletown and Dayton organized a cost group and had Mr. Runge make an analysis of their costs. Immediately afterward the foundrymen of Cincinnati were asked to meet with this newly formed group at Hamilton. From the discussion that followed, the Cincinnati foundrymen got the impression that Mr. Runge's cost analysis had showed them that their costs were higher than they had been estimating and they wanted some advice as to how to reduce them. As members of this group had been cutting prices in Cincinnati during the last six years, and since they failed to cooperate with the Cincinnati group in matters relating to molders' wages on several occasions the Cincinnati group was not very enthusiastic as to doing anything that would add to its existing troubles. The Cincinnati attitude was to let Hamilton and Dayton work out their own salvation and when they actually accomplished something that would benefit the foundry situation, the Cincinnati foundrymen would quickly follow.

As to the system, I think Mr. Carter has covered everything and I only need to say I believe it is a good thing to have a uniform system. However, I believe that if a group in one locality adopted one system and another group, say 100 miles away, adopted some other system, there would be little chance of very great differences in their respective costs, provided that both systems were based on sound principles of accounting. As the principles of cost accounting become better understood the results of various systems must undoubtedly come into closer agreement.

The efficient foundry, as Mr. Carter pointed out, will always have lower costs than the inefficient one, but they must figure their costs in the same manner, in order to show the conditions as they actually are.

In conclusion I wish to give you the opinions of the seven members in our group regarding the adoption of the Runge system. In almost the same words they said "It is the best thing that ever happened for the Cincinnati foundrymen." They have become acquainted with each other and know that their fellow foundrymen are their friends rather than their enemies.

Discussion

Chairman A. E. Hageboeck: There are two questions which haven't been fully answered here. One question was asked as to how to start a uniform group. I am wondering if there is someone who would like to tell us in about two minutes just how to start a group? This is an experience meeting now.

Mr. Delco: I believe I can answer it in this way. First, you must all of you agree you want to do the things uniformly. I would say after you have done that, the next thing is to get your organization together, and employ a man who doesn't talk too much, a man who will really treat the information confidentially. So, first, you have the desire for the system, and, second, you have the man who can carry it out.

I believe the third step is for each foundry to adopt a uniform set of accounts, expense accounts that will clearly distinguish all the major classes of expense in the business. I believe the next step would be to adopt a uniform classification of expenses. And I believe the next step would be an agreement on the part of all how to apply the burdens in the foundries, calculating the cost of the job. And I believe the last and final thing would be the agreement on the uniform method of calculating. If you can really adopt those things and do it together you will have something to start with.

Chairman A. E. Hageboeck: I want another question answered a little better and several men here, I think, can answer it. I would like to have it answered definitely and briefly. The question came up as to the distribution of expense, labor, and machine costs in the foundry or molding department. Certainly that is a very important question and I think it should be answered probably a little more fully than it has been up until now.

W. J. Corbett: That is a very difficult question to answer briefly, and all I can say is that you have to take into consideration your entire classification of accounts and methods of distribution, not only the overhead expense in the molding department, but the overhead expense which is general to the entire business. I think it depends largely upon the method

of distributing the entire overhead, just how to arrive at your overhead for the different classes of work.

MR. KALES: Mr. Chairman, that was my question and the point I would like to have made clear by somebody is, is it fair to charge that item of overhead on a big machine and distribute that overhead against all the other work? Or should that be figured in on the particular work to which that expensive equipment is applied to?

CHAIRMAN A. E. HAGEBOECK: Mr. Belt, do you want to do the thing I am trying to get somebody to do?

R. E. BELT: Mr. Chairman, that is a pretty difficult question to answer, not knowing the facts in the particular foundry. It would take an analysis in the particular foundry to determine just what should be done. Ordinarily it isn't difficult in most of the foundries which are making heavy work and light work, because the work is performed in different ways, the heavy work in one way and the light work in another way. Where a crane is a part of the equipment, the expense of operating that crane, such as labor, supplies, depreciation and taxes, etc., should be charged to the work that that particular machine produces. In other words, the work that requires expensive machinery to produce it should be charged with that particular expense. It sounds a little difficult and is a little difficult to explain, but it isn't a difficult accounting problem.

CHAIRMAN A. E. HAGEBOECK: The next gentleman whom I am going to call on has had many years' experience in handling cost matters. I take pleasure in introducing Mr. Don McDaniel, Vice-President of the Hamilton Foundry & Machine Co., who will talk to you on the subject of "Group Foundry Costs."

Group Foundry Costs

By Don McDaniels,* Hamilton, O.

I have been assigned the subject of Group Foundry Costs, and I believe I can best handle it by telling you about the operation of the particular group with which our foundry is connected and then discuss some of the benefits we have derived from it.

The idea back of the formation of cost groups is to make dependable cost data so easy to obtain and so low in price that no one operating a foundry will consider being without it. Selling prices are not touched upon. The federal government wisely forbids the comparison of selling prices by vendors, but it as wisely fosters the comparison of cost data. This is as it should be, for a man who knows his costs will not long continue to sell at prices that do not provide him a reasonable profit, unless he has deliberately set out to wreck his business. If reliable cost data are at hand, selling prices will take care of themselves. "Cost Groups" provide these data and at so small a cost to the individual member that it is negligible.

Such work as has been done by local groups has, of course, had as its primary object the study of costs in the individual plant, and then the comparison of the figures derived with those accumulated from the other plants in the group. The accumulation of the data is the function of a cost accountant, but the comparison is best accomplished in open meeting where the various items of expense may be discussed, compared with one another and with the average cost of the same items throughout the country. This latter information, of course, can be supplied only by the accountant and has to be accumulated by him in his work with the various groups he is handling.

Incidentally, it has been found that after two or three meetings of a group there is generally a better feeling existing among the members. As one discusses with his competitors the various problems of management brought forward by comparison of

*Vice-President, Hamilton Foundry & Machine Co.

costs, it is rather easy to discard the idea that, with the exception of yourself, all those engaged in the business are quoting foolish prices. Sometimes you learn that when you have gotten an item of cost down to what you think is absolutely its lowest figure, someone is doing better, and probably he will be glad to show you how he does it. The old idea of trade secrets is fast disappearing, and those who are advancing fastest are the ones who are freely exchanging their ideas with others.

In our Miami Valley Group we have at the present time eight members, all being gray iron foundries. These are subdivided into Class A, consisting of three "light" shops averaging less than 700 pounds per day per molder, and Class B, five "heavy" shops averaging over 700 pounds per day per molder. Mr. E. T. Runge, under the auspices of the Ohio State Foundrymen's Association, has been in charge of the accumulation and preparation of data, and has followed out his usual system of four divisions, namely, (1) Melt, (2) Mold, (3) Core, and (4) Clean and Ship. These are subdivided in the usual manner, and in addition, numerous other items, as agreed upon by the members of the group, are collected for comparison.

The product that the accountant concerns himself with in his accumulation of data is pounds of shipable castings produced and the unit used for comparison is the money expended to produce one pound of shipable castings in each of the various divisions and subdivisions.

After the data are accumulated, the accountant gives each foundry a number. He is the only one having knowledge of the entire lot of numbers assigned to the members, but when the data are distributed, each member finds upon his copy the number that has been assigned to his particular foundry. By the use of this method there is no reason why any member's number need be known to anyone other than himself.

Melt cost is subdivided into the following:

1. Pig and metals.
2. Coke.
3. Six per cent interest on plant investment.
4. Expense.

Mold cost is subdivided into:

1. Mold direct.
2. Mold indirect.

Core cost into:

1. Core direct.
2. Core indirect.

"Clean and ship" is the total of all costs incurred after the castings are delivered to the cleaning department.

Since this method accounts for all fixed expenses, operation of auxiliary departments, etc., and prorates them against the four major divisions, a total of the above items gives the cost of an average pound of castings over the period covered.

From these figures the overhead percentages may also be obtained to be used for estimating purposes.

In our particular group we consider the following auxiliary information valuable and it is shown on our reports:

1. Percentage of normal operation.
2. Ratio of molders to coremakers.
3. Percentage of returns from customers.
4. Pounds per molder per day.
5. Molding expense per floor.
6. Percentage molding expense to mold productive.
7. Percentage core expense to core productive.
8. Cost of clean and ship per molder floor.
9. Percentage of clean and ship to mold productive.
10. Cost per pound for insurance, taxes, 6 per cent on investment, depreciation, and salaries.
11. Percentage of above item to all productive labor.
12. Cost per molder per month for sand and supplies.
13. Cost per pound of castings for sand and supplies.
14. Cost per coremaker per month for core sand, supplies and oven fuel.
15. Cost per pound of castings for core sand, supplies and oven fuel.
16. Cost per pound for power.
17. Cost per pound for depreciation.
18. Percentage of depreciation to all productive labor.

19. Cost per pound for cupola expense labor.
20. Cost per pound for molding expense labor.
21. Cost per pound for core expense labor.
22. Cost per pound for clean and ship.
23. Percentage of all expense labor to productive labor.
24. Percentage of cupola expense men to molders.
25. Percentage of mold expense men to molders.
26. Percentage of "clean and ship" expense men to molders.
27. Percentage of core expense men to coremakers.
28. Percentage of total of all expense men to total of molders and coremakers.
29. Ratio of total number of molders and coremakers to total of expense men.

Along with this, a statement of the average pounds produced per month by each of the two divisions of the group is given, and compared with this on the sheet of each individual member is given the average number of pounds produced by his own foundry.

As the averages of the various items are discussed by the accountant, he gives comparable averages of the total of all the foundries he is serving under the group plan, so that one is able to compare each item of his costs with the average throughout the country. If one finds himself with costs well below the average in all departments, he can have the satisfaction of knowing he is doing his task well, but if he is high in some items, he knows where to put his first efforts.

In our own particular group we have decided that a detailed cost sheet should be made up quarterly, under present conditions. Labor rates and costs of materials have remained reasonably stationary for some time past. Should conditions change, monthly checking might be necessary, but at present we see no need for the additional expense this would entail. Our meetings are held at night, dinner usually being served, and then the remainder of the evening being taken up with the study of the report. We have found the subject so interesting and the questions asked so many that we cannot cover the ground satisfactorily in the time one generally feels can be given to a noon-day meeting.

I do not believe I am incorrect in stating that in a good many localities the foundrymen are not very closely tied together, except possibly at such times as they may be resisting an increase in wages. This is a bad condition for the members of any industry to be in, and anything that may tend to correct it is valuable. "Foundry Costs" is a subject that most all foundrymen are interested in, and the "Group Plan" offers an opportunity for bringing together the men of the industry that should not be overlooked. The fact that a group is well organized should also tend to discourage unreasonable demands for higher labor rates.

As I see the proposition, the advantages of the group plan may be summed up as follows:

1. Commercially accurate and dependable cost information at a minimum outlay.

2. Opportunity for discussing cost problems with not only a qualified cost accountant, but with expert foundrymen as well.

3. Opportunity of meeting with men in your own line of work and getting them to help you solve your problems.

4. Provision of a subject that will be interesting enough to hold local associations together where other reasons fail.

5. Last, but not least, the good fellowship resulting from knowing your competitor better and helping him out of his troubles.

I might say that the cost on such an outfit as we are trying to run is very nominal. The consultant checks over our foundry in half a day and his cost does not exceed $30 per quarter for our foundry. Of course, if we were in some locality some distance from Cleveland his traveling expenses would probably run up higher. But we have found this information very valuable, I am sure. Our experience has been the same as Mr. Carter's and Mr. Wessling's. Our particular group has only been in existence a few months; in other groups it has been in for a matter of about 12 years. But it is certainly a great help to have a group cost system.

Discussion

Mr. Hansen: I was wondering if it would be possible to form a non-ferrous group. Of course, I am in a place (Peoria) where a group in our city wouldn't work, for there aren't enough foundries to make a group. But could a group be formed covering a radius of 100 miles, say, or 150 miles? Would a group like that work out? I know there hasn't been much done in the non-ferrous line up to the present time. But I judge from what you say you are going to try to do something this coming year. I am interested in seeing a group formed that would take in quite a territory.

Chairman A. E. Hageboeck: I will answer that question just by reciting a little experience that happened a year and a half ago. I received a letter from a foundryman in a neighboring state of ours stating the gray iron foundries in that state wanted to get together and form a group, such as had been discussed at some of the A. F. A. meetings. They wanted to know if I wouldn't come out and help them. Well, I did. I suggested they get their crowd together and that we have a dinner at one of the hotels and that we talk it over.

We discussed the matter for about three hours and then I recommended that if they were interested that I would suggest a man who could come and talk to them and give them the details of how the costs would be handled. What I had told them was the general things the foundry executives would be interested in. They said, "How much will it cost?"

I said, "This man is coming by here in a month or two and his charge is $50 a day. If you fellows want to chip in $50 I think he will stop over a day." And we finally worked it out so he would only stop a half day.

There were some interesting foundrymen in that group. One man was a molder. He had a partner who was a molder, and with ten other molders they ran a foundry. However, they made a start and at the end of a given period they had one of their meetings and decided to go ahead for three months. And at the end of three months they decided to go ahead for a year. And now, at the end of 18 months, they are a very healthy group of foundrymen who are comparing their costs and have made very good progress.

That is what you have got to do. The American Foundrymen's Association cannot do that for you. You have to work out your own little problems; get your men together and hold meetings. If you will write to any of the members of our Committee I think they will help you as individuals, but the A. F. A. is not in a position to foster these groups.

It has been mentioned, and it is a fact, that there are 200 gray iron foundries now working on this method explained here this afternoon. It would be a mighty fine thing if these gray iron foundries could get together and form a national group so they could have representation here and other places as do the steel and malleable.

J. L. CARTER: I just thought perhaps I had better make one more statement about our Newark group. We have both open shops and union shops in our group. I think there are about seven open and five closed shops. And I want to say that there are only about two foundries that have withdrawn from the work since it has been started. One of the foundries we took into the group without expense to him. We paid the money from our own pockets. He is still figuring his costs, although he isn't a contributing member to our group.

The other one was a large manufacturing organization which came in for a while. Later their superior officer said it wasn't worth while, due to the fact they were not a jobbing foundry and did their own work.

None of the foundries have gone out of business and almost all the foundries in the group have been fairly successful and have made a very satisfactory profit. Our group is expanding and I am quite sure it is going to expand further.

Apprenticeship as a Labor Stabilizer

By A. W. Gregg,* So. Milwaukee, Wis.

The benefits to be obtained from a policy of training apprentices can be realized only after a considerable period of time. They are best appreciated when we compare labor conditions several years back with those of today.

Before establishing our apprentice training department we depended upon transient labor and that which we could obtain through advertising to supply our demands for mechanics of all kinds. Like most manufacturing establishments, these demands fluctuated with business conditions and usually when we were looking for men everyone else was doing the same thing.

When a sudden rush of business demanded an increased force of molders, machinists and other tradesmen, we hurried requisitions to the employment department and then waited more or less hopefully to see what it could secure for us. Employment agents were sent to distant cities, advertisements were placed where we could place them. Green men were brought in who either failed to meet our requirements or needed a great deal of training to make them do so. We probably stole some men from people who were our friends (or should have been our friends), and had like treatment accorded to us.

To say that we have entirely gotten away from such conditions would be to paint the millennium, but we are very happy to say that to a great extent they are getting to be a thing of the past.

During the latter part of 1926 our steel foundry was operating at approximately 70 per cent of capacity. During January of this year the demand for castings made a sudden increase to full capacity and the foundry has met this demand (which is an increase of approximately 50 per cent) *without hiring a molder.*

About 15 years ago the scarcity of skilled help in the Milwaukee district forced upon the attention of all manufacturers in Milwaukee County the importance of establishing apprentice

* The Bucyrus Company.

training activities. Bucyrus Company at that time started to put on apprentices in a rather haphazard manner, but it is only during the last 8 years that we have had a really well-organized department. At about this time Mr. W. W. Coleman, president of our company, set a goal which we feel we are today approaching. That goal was to put ourselves in such a position that it would be necessary to employ only apprentices and common labor. Since that time we have pursued a consistent policy of training men for all positions in our plant, including skilled and semi-skilled occupations. The majority of men whom we now hire commence work in either the Apprentice Division or in our construction and yard departments. In connection with the latter, the foreman of our construction crew recently counted about 300 men in our South Milwaukee plant who had started originally in his department and had been transferred to other departments where they could improve their earning capacity. Among the semi-skilled positions which can be filled from the labor gang we can mention crane men, steel chippers, flame cutters, molder helpers and molding machine operators. We very often have men who are employed as laborers apply for a transfer to one of our various apprenticeships. When this occurs, a man sacrifices his immediate earnings for the future. Many of our apprentices are obtained in this manner. It is of interest to note that the foreman of our steel foundry chipping room and several men occupying important clerical positions were originally employed by us in the labor gang. We believe that the nearer we come to a 100 per cent home-trained organization, the more efficient we will become.

A recent census of the mechanics in our South Milwaukee plant shows the following percentages of home-trained men:

Department	Per Cent
Machine Shop	65
Erecting Department	75
Engine Shop	65
Pattern Shop	70
Night Machine Shop	66
Foundries	78
Plate Shop	90

It is self-evident that our mechanics would disappear in one generation if none of us trained apprentices. We therefore have the choice of training our own mechanics or depending upon someone else to train them for us. We find that our home-trained mechanics are more likely to develop into loyal, steady employes than those secured from outside sources. People trained in this fashion absorb a home spirit and the company's policy. Our records also show that they are our largest producers and premium earners. Our largest and most costly machine tools are being operated today by graduates of our apprentice class and the largest and most difficult castings made in our foundries are being molded by home-trained molders.

Approximately 60 per cent of the men employed in our two plants own or are paying for Bucyrus Company stock. We consider this to be a pretty good evidence of thrift and loyalty and an indication of a stable condition of labor.

That labor turnover has been materially reduced during recent years is best evidenced by the following report which is based upon figures obtained from the Milwaukee Branch of the National Metal Trades Association.

Labor Turnover Report

	Bucyrus Co. Rate Per Cent	*Average of Milwaukee County Per Cent*
1923	208	170
1924	91	90
1925	81	110
1926	60	101

Another record showing that our employes stay with us is the following:

	Per Cent
Employed over 10 years	24.8
Employed 5 to 10 years	11.8
Employed 1 to 4 years	47.3
Employed less than 1 year	16.1

We attribute the improvement in our labor turnover figures very largely to the effect of our home-training policies and the personal relationship which it enables us to maintain with all our

men. It has always been our policy to keep our employes in a satisfied and happy frame of mind. When an apprentice completes his course and enters the ranks of mechanics, we do not lose interest in him but endeavor from our efficiency and other records to determine if he is doing the proper kind and the proper amount of work. When we find a man who for any reason is slipping, we endeavor by personal interviews to discover the cause of his trouble, whether it is personal or otherwise, and try to help the man out of his difficulties. Our manager of industrial relations interests himself in anything which pertains to a man's welfare either at home or in the shop and has helped many a man who was discouraged or disheartened, for any reason whatsoever, to improve his frame of mind.

The graduates of our apprentice class furnish a splendid source of supply for future foremen. Six of the important foremen in our plant today have served an apprenticeship in the shops. Among these may be mentioned the foreman of our core room, tool room, engine shop, the supervisor of apprentices in the machine shop, assistant foreman of our pattern shop and the assistant foreman of our plate shop.

We attempt to maintain a ratio of approximately 1 apprentice to every 15 men employed. The large majority of the graduates of our apprentice class remain in the employ of the company. During 1925 21 young men completed courses, of which 19 are still on the payroll. During 1926 20 were graduated, of which 16 are still in our employ. When an apprentice completes his course we do not bring any special pressure upon him to remain with the company and if he is desirous of obtaining experience in other shops we wish him good luck and tell him that if he desires to return later we will be glad to put him to work if the opportunity permits. We find that most of the men who leave us in this way return in 6 months to a year and are, perhaps, better satisfied for knowing something of conditions in other plants.

Our most important departments are foundry, machine shop, plate shop, pattern shop and erecting department. In these departments we are training molders, core makers, welders, machinists, tool makers, structural workers, engine builders, pipe fitters, erectors, electricians and pattern makers.

Two years ago we encountered a very troublesome shortage of outside erectors. It has always been difficult to obtain a sufficient supply of men who can erect our shovels and dredges in the field. It is especially necessary for this class of work that we have very competent men, for it is necessary to send them to all parts of the world. Two years ago a committee was appointed known as the Outside Erector Apprentice Committee, which consists of our works manager, manager of industrial relations, superintendent of outside erection, assistant secretary of the company, assistant to the works manager and the superintendent of our Evansville plant. This committee drew up a plan for a course of training to fit men for outside erectors. A requisite for admission is that a man shall have served a four-year machinist course. The course consists of shop work in all of our important departments, supplemented by lectures and schooling in electricity, mathematics and mechanical drawing. Two recent graduates of this course are at the present time employed on their first outside erection jobs.

For many years we have maintained a course which is open only to graduates holding degrees in engineering from well recognized engineering schools. This course is designed to supply future requirements for executives in our sales, engineering and manufacturing divisions. The course consists of 12 months' work in our various departments and shops and is supplemented by monthly evening meetings which are attended by executives of the company and the committee in charge of college apprentices. At the end of 12 months the man is asked to express a preference for the department which appeals to him most strongly, and after his decision is approved by the committee for college apprentices he is put through a special training for 6 months under the supervision of the department head to whom he will eventually report. Many of the branch managers in our sales offices and several of our most important engineers, our foundry superintendent and his assistant, the superintendent of outside erection and two of the company's four officials are graduates of the college apprentice course.

We have found that considerable effort and close attention is necessary for the establishment and maintenance of a success-

ful apprentice training course. The co-operation of all executives and foremen is especially necessary. We have found that supervision of apprentices beyond the supervision which the foremen can give is very necessary. We have always been proud of the splendid co-operation given to our apprentices by the rank and file of our mechanics. Incidentally, many of the apprentices are sons of men employed in the plant, and so far as possible preference is shown to sons of employes when we are selecting apprentices.

We have found that it is very important to select as apprentice supervisors men who are not only good mechanics but in addition are patient, tactful, firm, and above all, fond of young men and sympathetic with their peculiarities. A good supervisor of apprentices is one of the prime requisites of a successful apprentice department.

It is well to exercise great care in selecting apprentice material and to drop from the class during the probationary period all of those who fail to show decided aptitude for the work selected. Our best apprentice supervisor discards approximately half of his probationers during the first month, and his slogan is "that a boy who is only half-way good is no good at all."

We have *not* found that apprentice training is costly. In the foundry we have a class of 25 boys who are producing castings which cost us very little more than those produced by the mechanics. The apprentices produce about one-half of what a mechanic would produce and as their pay is approximately one-half of a mechanic's, there is practically no increase in the cost of molding. During 1926 our foundry apprentice class averaged 28.2 per cent premium earnings as compared to 43.6 per cent for the molders. The rates were set on the same basis.

In conclusion, we can say that there is a tremendous satisfaction to be obtained from a properly conducted apprentice program. When we sign up a boy or young man to a contract and watch him develop into a skilled, well-paid mechanic, we feel that we have benefited the apprentice, his family, the community and the company. Further, we have done our duty to the industry as a whole.

Making Apprenticeship Pay Dividends

By W. B. Perry,* Bay City, Mich.

It is five years since Herbert Hoover's Commission on Waste Prevention in Industry reported that 50 per cent of the waste in industry is caused by management. And unless management is taking advantage of every opportunity, that indictment will stand for a long time.

In starting and properly operating an apprentice program—a *real* program planned with care—management is striking at two of the biggest contributors to that 50 per cent. It is usual to talk about apprenticeship as a duty or as something which will be of benefit in future years. Sometimes we even hear employers speak of it as a sort of charitable contribution to the welfare of their community. Actually—and this is being proven every day—apprenticeship is a real economy for *today*.

The two contributors to waste mentioned above are labor turnover and poorly trained employes. Turnover is generally recognized as a costly thing; although the entire cost for any organization is most difficult to compute. Reduction in turnover has long been claimed by proponents of apprenticeship and we actually have some very interesting figures from Milwaukee and elsewhere to bear out this contention.

If you take a young man into your organization for three or four years and not only teach him a trade but also "sell" your organization to him, it is only natural that his length of service with you will be longer than if he were just "picked up" from the outside and given a job. Then, too, you have only to *teach* him your methods—he has nothing from some other plant to ***unlearn***.

Another point in this connection is this: when you go outside—perhaps even out of town—for your mechanics, is not the very wanderlust which brings those men to you a drag which will

*General Superintendent, Industrial Works.

pull them away? With apprenticeship, you are taking the young men of your own community and turning them into good mechanics as well as useful citizens; and thus counteracting another cause of turnover.

We have heard much about the value of apprenticeship in building up a so-called "flying squadron" in the plant. But perhaps we have seen so many other advantages in this that the matter of saving in turnover has been slighted. Whenever apprentices are able to fill in a breach during an emergency, they make unnecessary the hiring of men who must be laid off as soon as the emergency is over. Is that not a real saving in turnover? How much can be credited to the account of apprentice training for every such case?

It is hardly necessary to mention the value of proper training, for you gentlemen have all experienced the difficulty of getting so-called molders, coremakers and patternmakers who were not really trained and who added much stock to the scrap pile as well as much grief to your production department. But just remember that every dollar saved by having properly trained men is to be credited to the account of the system which trains those men.

We have heard only too often the statement that apprenticeship costs too much for the average manufacturer. As one employer put it: "I can't afford to take boys into my plant and teach them a trade. My plant is too small to have all the bother." But we are coming to realize more and more that employers can not afford *not* to train young men—and that obtains for the small shop as well as the large one.

At the Detroit convention of the A. F. A. last year we heard how the manufacturers of one community were solving the problem of making it possible for the small plants to work out a program.

The manufacturers of Bay City, Michigan, are at present just at the beginning of a program which will make apprenticeship available to all of the many plants in this community. Bay City is an industrial commuity of some 50,000 people, situated just outside the Detroit automobile district. A list of its manufactured products would range from radios to ships, and with

but a very few exceptions the plant pay rolls are considerably below one hundred employes. When the local chamber of commerce became active, there was only one plant employing apprentices and that plant had but very few. It was found that many of the young men of the community were leaving home to work in other cities and at the same time the industries were forced to go out of town to obtain the mechanics necessary. Boys leaving school were soon aware of the fact that the employment offices of their city had little time for those who were "looking for a job" without any particular training for any job. The disadvantage of leaving home was overcome by the greater earnings possible in so-called "production" jobs which required little or no training and which were available only fifty miles away. On the other hand, to indicate the attitude of these boys, the one plant where apprenticeship was a tradition found that its waiting list was always quite large.

A committee was appointed by the chamber of commerce to investigate the situation and to draw up recommendations for action. This committee obtained the services of Mr. H. A. Frommelt, consultant on apprentice training, and a preliminary survey was made as a basis for future action. This survey showed that there were approximately forty plants which could be drawn into some sort of community plan. This included some six or seven foundries, all of which required the highest type of mechanic. Now—and here is the salient point—of the entire group of plants only *two* could adequately maintain an apprentice program within their own walls. With a plan of cooperation between the various plants *every single one could take part.* The investigators found that there were just twenty apprentices where the normal quota, according to accepted standards, was close to four hundred.

The need for action was most apparent and the committee did not hesitate to get under way. After the plan of action had been worked out, the superintendent of the local schools was invited in and his cooperation requested. Perhaps, like many another school man, he had long realized the need but had found himself powerless to meet it. Now he was quick to offer his whole-hearted assistance in a plan which was so sorely needed.

Arrangements were made for him to provide class room space and supervision for the study portion of the apprenticeships.

The next step was to call together representatives of all the plants concerned for the purpose of outlining the proposed action and to begin the "selling" of the idea to the city. Of course the response was enthusiastic from the employers, for most of them had been looking for just such an opportunity. Now the committee could begin to sow the seeds of interest in the community to get the "raw material" for the operation.

Simultaneously, work was begun in the plants and in the community. Through the superintendent of schools, a program of talks was given before the students in the high school to gradually build up a desire among the boys for trade training. The local papers assisted by a series of articles on the general value of training and the particular advantage of learning in local industry. The other half of the job was to obtain a marketable product and hence a particular survey was made to outline for each plant its own program and to tie together those plants which needed to cooperate because of incompleteness of individual schedule. Schedules of work and study were worked out for each trade and a uniform wage scale was agreed upon. In each plant steps were taken to get the right kind of cooperation from the various foremen. This is to be a successful program and no stone will be left unturned to make it so. We realize the great value of the experience of other plants and other communities and do not hesitate to acknowledge a debt of gratitude. And right here it might be stated that the activities of the American Foundrymen's Association have been largely instrumental in providing the impetus for Bay City.

At present there are only some fifteen boys fully enrolled as apprentices under the new plan. These boys are spending four hours of each week in studying the related subjects so necessary to dovetail with their shop work. Each boy is enrolled in a correspondence course particularly outlined for him, thus relieving the local school people of the great task of preparing suitable texts and courses. The shop work is being carefully supervised and caution is stressed in the selection of the new boys. Much of the grief of installing a program of this sort can be eliminated

if a little vocational guidance is employed in placing the young recruits.

There are no records of accomplishment to talk about—not yet. The whole thing is too new to expect anything of the sort. A start in the right direction has been made and Bay City is satisfied that the results will be all that can be expected. The important thing for this paper to point out is that not one of the member plants is going ahead with the idea that it is doing a charitable act; they all realize that it is simply good business and a determined effort to cut down that 50 per cent.

A Publicity Program Justified by Correct Methods of Apprenticeship to Attract Young Men

By H. J. Roesch,* Chicago, Illinois

There exists a popular, but mistaken, idea that the young man of today does not care to work and insists on having a white collar job. To those of us who are actively engaged in promoting apprenticeship in various industries, this amounts to a libel of the younger generation. How any man, or group of men, with this idea, can expect to carry on a successful apprenticeship in their factories is a mystery that I for one cannot solve. You ridicule him for wearing bell-bottom pants, which he can change without removing his shoes, and forget that you choked your ankles with the then popular peg-top trousers, of which you were so proud.

Gentlemen, the American boy of today is the cleanest, most upright, square dealing sort that this nation has ever had the pleasure to call her sons. Any other preconceived notion that you, as individuals have formed, must be changed, for how can you expect to sell yourself to the boy if you are mentally prejudiced against him?

You want him to come into your foundries to learn the trade. What have you done to attract him? Employers tell me they are willing to pay 50 cents an hour to the apprentice, but they do not stay. I do not wonder that a boy does not want to shovel sand at 50 cents an hour when he has unlimited opportunities to earn as much at work which is easier. On the other hand, if you offer the boy an opportunity to learn the trade with a clear, concise, detailed statement of what you are going to teach him, backing up this program in your shop with a man who knows boys and will see to it that they get their training, you will not

*Director of Apprenticeship, Chicago Branch, National Metal Trades Association.

have to worry about paying more than a fair wage, and you may be sure that he will stick.

To this extent you must be sold before you can expect to start a publicity program. You can not change your minds after you get the boys.

In order to attract boys to your plants, it is necessary to educate them as to the opportunities which are present to a young man, skilled in the theory and practice of the art of molding. What have you to offer: a good living, promotion to executive and managerial positions, and an opportunity to go into business for himself? Tell him how the molder works. Point out the interesting features of the trade. Indicate what he should know about science, chemistry, metallurgy, and the art of handling men, materials and machinery. In what kind of homes do the molders live? Do they save any money? Do they own their own homes? How do they rank with other tradesmen? Why is the occupation important? What is the future of the trade? What are the working conditions? What are the necessary physical and personal qualifications? What tools and materials does he use? Tell him how you are going to teach the trade and then stick to everything you have said.

The Chicago branch, National Metal Trades Association, has been actively engaged in promoting apprenticeship since October, 1926, when a director of apprenticeship was engaged to devote his full time to the work. A survey of the needs for apprenticeship was made, and the results were astounding. Eleven districts were formed, by grouping the membership plants geographically for the purpose of efficient handling. Each district includes a residential section, and is accessible to a technical high school. This was done to minimize the number of educational and personal contracts which are being made, and reduces the amount of effort which would be necessary in a city-wide program. When we found what we needed, what we had to offer, and most important, what we could and would do, we wrote a pamphlet setting forth all these things, which we are backing up. This pamphlet is furnished to the key persons in the educational sys-

tem. It is now being used as vocational guidance material in the schools located where we are promoting apprenticeship.

Apprenticeship talks are given periodically in the schools by the apprenticeship director of the Chicago branch. The interest shown by the students is most gratifying. After these talks, applicants come to the office where the apprenticeship system is explained to them and they are given the promotional literature. At the present time we have a number of high school graduates waiting to serve apprenticeships in one of the nine trades which we are teaching.

The secret back of this is that we are offering each boy an intensive, practical, industrial education coupled with one full day of related instruction in one of the city's continuation schools. The wage is incidental to his training. Each employer appoints someone to be definitely responsible for the supervision of the boys in the shop. It is his duty to see that they are advanced according to the schedules contained in their contracts. A monthly report is sent to the parents to maintain their interest in the welfare and progress of their son.

The boys, when hired, must be accompanied by either parent. This is done to show their parents under what conditions their son will be for the next 3 or 4 years. The minimum age required is sixteen. The boy must have the equivalent of an 8th grade education. Graduates of a 4 year technical course are eligible to receive a credit of one year on their term. Graduates of a two year technical course are eligible for a credit of six months. Boys with previous shop experience are given credits at the discretion of the company. Graduates of an apprenticeship are presented with a bound pocket record of their training, certifying them as journeyman mechanics. The apprentices are now attending classes in related instruction at the Washburne continuation school for a full day each week.

Most school systems in the country make some provision for disseminating to their students such information about industry and trades as they can obtain. In Chicago this activity is taken care of by a separate department called the Vocational Guidance Department, which is responsible for publishing information about the various trades, and sponsors lectures on industrial in-

formation. These people are anxious to work with us, as they know that the great bulk of students will enter industrial pursuits upon leaving school. They have the interest of the boy and girl at heart and are ready to give a helping hand to start these young folks on the right road to becoming responsible citizens of the future.

Here is the activity around which you should build your publicity work. It is an educational program which must be spread through the schools in order to become successful. It cannot be accomplished over night.

The foundrymen alone cannot succeed in popularizing apprenticeship. In order to be successful, it must be carried out on a larger scale. Every trade or craft is suffering from the scarcity of skilled men.

We should be ready and willing to help the building trades or any other group which is sponsoring an apprenticeship program. Boost their system and they in turn will boost yours. Get behind any bona fide industrial educational movement and give it your whole-hearted support. We must think in terms of apprenticeship. Talk apprenticeship to your neighbor and your competitor. It is only by constant striving to reach a goal that we can hope to attain it.

When you return to your respective communities, after leaving this convention, make it your business to ascertain what is being done in regard to industrial education in your local schools. If your state is engaged in promoting vocational education, it can be of service to you through this activity. Organize the foundrymen in your community for the purpose of promoting apprenticeship. Inform your local school men as to the opportunities for young men in your plants. Solicit the aid of your State Vocational Education Department in promoting the work, and help them with their problems. Keep everlastingly after it and in time you will find that parents will again be willing and eager to have their sons learn a trade. Bring the mechanic to the same social status of the office or bank clerk, and your problem is on the road to a correct solution.

Twenty years ago an apprenticeship was more or less an

accepted fact. The advent of automatic machinery did away with the necessity of learning a trade in order to earn a good wage. Apprenticeship has been on the decline for years and we must be everlastingly hammering away at it now, if we wish to again place it on the same level at it was when we learned our trades.

Patience and perseverance with the young man, and action on our part, will bring about the results for which we are now striving.

Careful Selection and Supervision Are Important in Reducing Apprentice Turnover

By W. Watson,* Milwaukee, Wis.

The Allis-Chalmers Manufacturing Company has always realized the absolute necessity of keeping a full quota of apprentices at all times, realizing fully that in our class of work, which is all special, we have to have trained, efficient men at all times capable of taking the places of the older men who are continually either being promoted or dropping out of our employ for various causes.

In order to keep up the quota it is obviously necessary to have suitable material ready at all times to fill vacancies. To do this the necessary propaganda is supplied through such agencies as our public and vocational schools, shop employees and through the apprentices themselves as our works have gained a reputation as being a good place for a boy to learn a trade.

It is not my purpose in this paper to dwell upon any particular trade but I should like for a moment to digress to the extent of giving you a brief outline of how we overcame our apprentice problem in our foundries.

It had always been the practice to keep the new boy helping around on various jobs without definite direction, which to him was uninteresting and he was constantly clamoring for a change or else quitting in disgust—the apparent indifference on our part and the nature of the industry were too much for him.

We realized that if we were to train apprentices in our foundries a drastic change in the prevailing policy would have to be made. In June, 1923, it was decided to set aside a space in our No. 1 foundry and put an apprentice supervisor in charge and place our boys under him. The man chosen for this job

*General Works Manager, Allis-Chalmers Manufacturing Co.

was, of course, a practical man and a man who liked and knew boys.

At the time this change was made we had 17 boys who were serving molder apprenticeships—today we have 50, our quota, and a waiting list, also a smooth working apprentice unit in both foundries. We feel that we are at last on the road to a real solution of the molder problem. We will state in conclusion of this particular subject that our foundry apprentice program is running as satisfactorily as any department of our apprenticeship divisions.

We find that one of the most important things in putting any kind of a system into your plants is to have your foremen and superintendents in sympathy with the movement. One foreman in an organization who is not in sympathy with this, or any other movement, can do more damage than can be offset by the good efforts of several foremen who are in sympathy with it.

Any manager will find, when walking through his plant and in talking with the foremen brings up the subject of apprentices, that the foreman who wants to show him some of the good work his boys are doing that that foreman has the right idea of what you are trying to put across. When, however, a foreman will immediately start to tell you about the trouble he is having with the boys you can make up your mind that that particular foreman is spending too much time trying to point out to you the inefficiency of the boys, not realizing that he is dealing with boys and has to handle them accordingly.

Few people, I think, realize the changing labor conditions that have occurred in our country in the last 20 years. Up to 20 years ago if a young man was not able to continue his education and wanted to be somewhat better than a good laborer he was forced by circumstances to learn a trade. About that time the automobile came into existence which immediately brought forth the so-called "mass production." Also about this time electricity had made possible the introduction of a great many labor saving devices for the household, which were also manufactured on mass production which brought forth the so-called *specialist*. A young man would be put at one operation, a price set for this operation and he would become so proficient in this

particular work that he naturally demanded and made high wages, little realizing that he was practically making out of himself a part of a machine.

After this change came the great war which took a great many of our young men. For a number of years at this period not only the automobile industry and the manufacture of electrical appliances, but also the war got the young men, and their parents, into the habit of earning big wages. All this brought about a higher standard of living and it had a tendency to make parents and the young men feel that this higher standard of living could be maintained indefinitely. I feel now though that the young men and their parents are realizing more and more that to learn a good trade is something that is going to help them to maintain their standard of living for a longer length of time than to get high wages for a short period of time and be nothing but a cog in a wheel caused by mass production.

Since the war most progressive companies have organized along the lines of good management in handling boys to make future tradesmen out of them. Our system of procuring boys is through a man whom we call our apprentice supervisor whose duty it is to get the boys, visit their homes and talk to their parents. Then after there is a thorough understanding between the company, the boy and the boy's parents or guardian, he is offered a position as a trade apprentice. This system applies to all our apprenticeship courses, in which there are eleven different grades represented. The technical students, of whom we have a great many going through our plant, are picked by personal visits to the different colleges by our apprentice supervisor.

When the boy first comes into the shop he is given a physical examination by our shop doctor. This is done for two reasons: First, we want to know that we are getting fairly healthy boys to start with. Secondly, the doctor takes it upon himself to give the boy a talk on hygiene and we feel that this will have a lasting impression on the boy, as boys at that age, from 16 to 18 or 19, given a physical examination will probably remember it for a long time and it will have a good moral effect on the boys. The boy also has a personal talk with the superintendent in whose department he is to work. Thus he has interviewed the four principal men in his apprentice training before starting.

After all this routine is gone through the boy is then turned over to the department that he is going to start in and he comes in contact with what we call our shop apprentice supervisor, of which we have 8 at the present time. All during the period that this boy is in this department he is in constant touch with this supervisor who shows him how to do the different operations that he is supposed to do and also looks after his general welfare.

We have a regular fixed contract so that the boy knows approximately how many months or weeks he is going to be kept in each department doing a certain class of work. This is written right on the face of his contract and we religiously follow this up. This is done by our apprentice supervisor who originally hired the boy. For a double check on this, so as to avoid any controversies, we have the chief clerk of our manufacturing department check the apprentice supervisor up as we try as far as possible to show the boy the honesty of the contract and the honesty of our purpose in living up to it.

We try as far as possible after the boy is through with his apprenticeship to find a position for him in our own organization. Sometimes we find a boy is a little dissatisfied and we always encourage that boy to try some other shop. We think this works well with some boys because they find that all shops have rules and regulations, that no shop is hiring anybody just to give them a job as they all have a well defined reason why they hire men.

We have had a policy in our company for a good many years not to hire outsiders, as our president took the attitude when he first started that he thought there was something wrong with an organization that employed 6,000 to 7,000 men and out of this number they could not pick men for any position, unless the company took on some specialty from the outside which had been developed and we brought special men in with it. So our boys under these conditions always have something to look forward to and in the last number of years we have found very good positions for a great many of the boys who served a faithful apprenticeship with us.

We feel that there is not so much to this but what any company that so desires can start an apprenticeship by first getting a man to devote his time to it and secondly getting good

boys. The most important thing of all is to get the sympathy of your foremen and superintendents and have a regular fixed plan and deal honestly with the boys.

I feel that if every company would do this that in a very few years the manufacturers who are dependent on skilled mechanics to get out their work would be back in the same position as they were before the advent of the automobile and the electrical appliances which brought about mass production and changed the whole system of training labor.

The grades of apprentices in our plant are as follows: blacksmith, woodworkers, welders, machinists, pattern makers, molders, electricians, boilermakers, co-operative students, graduate students and draftsmen.

Metal Trades Association Launches a New Campaign in Milwaukee

By C. J. Freund,* Milwaukee, Wis.

There are at present about 950 apprentices in the Metal Trades Association shops of Milwaukee which employ a total of 25,000 men. Six years ago there were 460 apprentices in the district, which shows an increase of 100 per cent. The apprenticeship affairs of the association are at present in the hands of a general apprenticeship committee of five members. These five are all officers and executives of their corporations. The general committee meets several times per year to establish general apprenticeship policies, to solve important general problems and to recommend appropriations. An operating committee of about 20 members, apprentice supervisors in the various plants, works under the direction of the general committee. They carry out the general policies, execute the apprenticeship plans and activities of the Metal Trades Association and solve individual problems as they arise. This committee meets regularly once a month and there are special meetings when necessary.

At the present time the efforts of the apprenticeship committee of the National Metal Trades Association in Milwaukee are being concentrated on the conversion of the 19 members of the association who do not yet employ apprentices. Although these 19 corporations employ only 2,000 men out of the total of 25,000 which are employed by the members of the Metal Trades Association in Milwaukee, the committee feels that apprenticeship cannot be considered thoroughly established until every single member of the association is active in the training of mechanics for the community.

This campaign was launched last October and will continue during the coming season and thereafter until apprentices can be found in every plant which is affiliated with the Metal Trades.

The first work of the committee in this campaign was to

*Apprentice Supervisor, The Falk Corporation.

discover the precise reason why these 19 corporations did not employ apprentices. W. J. Fairbairn, secretary of the Milwaukee branch of the association, has been very active in the promotion of apprenticeship and has kept a careful record of its apprenticeship activities. The matter was thoroughly discussed with him and his records were examined and it was found that the difficulties which prevented the establishment of apprenticeship in the 19 plants involved were largely as follows:

No. 1. Apprentice training in the small shop was considered to be impracticable.

No. 2. It was maintained that apprentices cannot be trained properly in a plant manufacturing a specialty product.

No. 3. Production methods prevent proper apprentice training.

No. 4. A number of plants objected that they could not train apprentices because of changes in organization, irregular work and other difficulties.

No. 5. Several employers felt that there was no need of training mechanics as there were always sufficient on hand.

No. 6. Others objected to the half day of school attendance per week which is required by the apprenticeship law of Wisconsin.

No. 7. A considerable number felt that apprentice training was necessary but for some reason or another constantly postponed beginning the undertaking.

It was admitted that these were real problems but at the same time, the apprenticeship records of the association showed that other plants in the district were operating successful apprentice training programs in spite of these very same difficulties, which indicated that they could be overcome. The problem was to discover a means whereby the 19 employers could be impressed with the successful methods used by other employers to solve these problems.

According to a plan recently evolved by the directors, the

various committees of the association are to provide a discussion of their work in connection with a series of dinner meetings for members of the association. The apprenticeship committee accordingly decided to present solutions for the various difficulties which prevented the further growth of apprenticeship at such a dinner meeting. Work was begun last November. Officials of the various plants in which the outstanding problems had been overcome were approached with a request to prepare a paper explaining how they had overcome the particular objections which stood in the way in their plant. The various subjects were assigned in such a way that the solution of each difficulty was presented by an official of a plant where such difficulty was considered to be greater than in any other plant.

After six months of preparation, the dinner meeting was finally held at the Pfister Hotel on Monday evening, May 16th. The dinner was attended by 102 people, all of them directors, managers and executives of Metal Trades shops with the exception of a very few apprentice supervisors who are members of the committee in charge. As far as can be ascertained, every one of the 19 corporations which employ no apprentices was represented by one or more officers. The program was well planned and executed without delay. The reading of the papers and discussions occupied exactly two hours and the interest of those present can easily be understood from the fact that only three persons left the meeting before the program was concluded. Of these three one was a guest and not a member of the association and the other two were officials of a corporation which has employed apprentices for many years.

The program was opened by Harold S. Falk, chairman of the apprenticeship committee, who welcomed all present and explained that the meeting was called for the discussion of some of the outstanding problems of apprenticeship with a view to making it possible for all members of the association to employ as many apprentices as they could. Thereupon he introduced Mr. Theodore Trecker, of the Kearney and Trecker Corporation, president of the Metal Trades Association in Milwaukee, who gave a brief resume of the history of apprenticeship in this district.

Thereupon Mr. Ernst Gies of the firm of Lutter and Gies read a paper entitled "Apprentice Training Possible in the Small Shop." The machine shop operated by Lutter and Gies has during 40 years never employed more than 50 men and has employed apprentices from the first day of its operation.

"Handling Apprentices in a Specialty Shop" was read by Mr. F. J. Roensch, general superintendent of the Louis Allis Company. This corporation is engaged in the exclusive manufacture of standard electric motors and an excellent example of a specialty shop.

The Cutler-Hammer Manufacturing Company is the largest manufacturer of electrical controlling devices in the world and the outstanding production shop in the Metal Trades Association of Milwaukee. Mr. A. F. Thompson, employment manager of this corporation, presented a paper entitled "Apprenticeship in Spite of Production Methods."

"Making Apprenticeship Work Through Changes in Organization, Irregular Work and Financial Difficulty," was explained by Mr. John Goetz, vice-president of the Kempsmith Manufacturing Company, which has been completely reorganized several times but has persisted in the employment of apprentices in spite of great difficulty.

Mr. W. C. Furnas, assistant works manager of the Allis-Chalmers Manufacturing Company, answered the argument that there are plenty of mechanics available by the very obvious explanation that "If There Appear to be Sufficient Mechanics Somebody Is Training Them for Others." Mr. Furnas was particularly well qualified to read a paper on this subject because the Allis-Chalmers Manufacturing Company has been training apprentices successfully for twenty years or more and has consistently employed more apprentices than any two or three other organizations in the district. At the present time this concern employs nearly 350 apprentices.

"Advantages of Part Time School Attendance" was read by Doctor Stewart Scrimshaw, manager of Industrial Relations for the Kearney and Trecker Corporation. Doctor Scrimshaw was the first director of apprenticeship for the State of Wisconsin and is probably better qualified to discuss this question than any other person in the community.

The last paper of the program was entitled "Benefits of Apprenticeship Should Overcome Hesitancy in Getting Started." This paper was read by Mr. A. W. Gregg, general superintendent of the Bucyrus Company. Mr. Gregg's outstanding discussion on today's program will make clear to all present that this subject was discussed with the advantage of long and very successful experience in apprentice training.

A short discussion followed the reading of each paper.

In connection with the dinner meeting there was a display of apprentice work in the iron and steel molding and pattern making contests of the American Foundrymen's Association and also a display of machine work made in a contest for apprentices conducted locally by the Metal Trades Association of Milwaukee. Also, Mr. W. J. Fairbairn, the secretary of the association, exhibited interesting charts showing the growth of apprenticeship in total and in the various trades established in member plants. It was generally admitted that the meeting was highly successful. In fact, two employers out of the 19 for whom the meeting was held requested assistance in establishing apprenticeship on the day following the meeting and others have doubtless been heard from since then. This program is the first in what is intended to be a series of meetings for the discussion of apprenticeship and the good results of the meeting will be followed up by a personal campaign by members of the operating committee.

Apprentice Training Situation in the Pittsburgh District

By Dr. C. B. Connelley,* Pittsburgh, Pa.

These few remarks come from the Pittsburgh district at the request of the chairman of the A. F. A. committee on apprentice training. In this district foundry apprentice work is meeting with the approval of the foundrymen of our vicinity; so much so, that the local apprenticeship committee is compiling a bulletin "Why the Foundry Industry," and devote considerable space to the work of the American Foundrymen's Association, especially the apprentice training.

Our local association at Pittsburgh had as the "guests" at a recent meeting all the apprentices receiving the foundry training that is fostered by our committee in the public school system. This was prompted by a story from Mr. Hartley, Director of Education of the National Founders' Association in which he said:

"Since restricted immigration has forced employers to recognize the public schools as an original source of labor supply, employers are justified in inspecting the schools with a view to offering suggestions regarding the effect of schools upon industry. As long as an industry could look to foreign countries to furnish the great bulk of its labor, it could afford to view public school activities in a detached manner. When an industry is forced by circumstances to depend upon the product of these schools, some attention must be given to the quality of the school product. In the very nature of things, another generation will find our industries being operated and, to a considerable extent, managed by persons who began their training in our public schools. By this time many present employers will have earned the right to enjoy the belated fruits of their labors. These industrial leaders are now interested, as a matter of protection, in character of youth the public schools are preparing to send to factories.

*Director of Industrial Relations, Carnegie Institute of Technology.

"Of one thing employers are quite certain. It is vastly more important that young men who come to industry are willing to work than that they are able to read Latin or even to perform difficult mathematical calculations. Technical information, although of great value, is much less important than a wholesome attitude toward work and social obligations. This is exactly the point of interest employers are beginning to manifest in public school instruction. Many national leaders, parents, and even school men, are beginning to ask if there is not something wrong with a school system whose chief aim seems to be to train our children away from work instead of training them into useful service in occupations."

The Pittsburgh Foundry Association met and agreed to follow this thought and took up the work with the Board of Education by developing classes in the Pittsburgh schools. Mr. Levitt, the associate superintendent, has sent to me the following report:

Foundry Classes in the Pittsburgh Public Schools

"In developing a number of varied trade courses in the vocational or trade schools of the Pittsburgh Public School System, due consideration has been given to the necessary cooperation of the particular industry involved. Until the industry itself decides that a trade course or trade courses would be of value to the industry, the school system has withheld experimentation. For the above reason, little has been done with foundry work until the present year. The industry itself has not been of the opinion that the time was ripe for public school classes in this kind of work. This opinion has been due very largely to the fact that the Carnegie Institute of Technology has been doing such excellent work in this field.

"In 1926 the Pittsburgh Foundrymen's Association, after several meetings had been held for discussing the question, came to the conclusion that there was a place in the old scheme of education for foundry work which could not be filled by the Carnegie Institute of Technology, but which could be filled properly by the Public School System. Various committees have been

appointed by the Pittsburgh Foundrymen's Association to help in developing the work in the following particulars:

"First, there was a committee appointed to write to the Board of Education requesting that the Board give careful consideration to the needs of training a certain number of boys in the trade school for jobs as molders' apprentices.

"Another committee was appointed to cooperate with the school officials in selecting the school plant where, all things considered, it was deemed to be most profitable to start the work experimentally. This committee selected a school plant on the north side, where a small room was available in the Phipp's Gymnasium Building. This room has been equipped by the Board of Education with some assistance by the Pittsburgh Foundrymen's Association as adequately as possible, considering the limitations of size. Another committee was appointed to assist in securing apprentices who would enter upon the part-time plan of apprenticeship work or to cooperate with the school officials to this end. Another committee was appointed to cooperate with the schools in developing a satisfactory course of study.

"As the result of the activities of these various committees cooperating with the school officials the Pittsburgh Vocational School is operating classes in molding at the present time. The members of these classes are either part-time molders' apprentices or boys regularly enrolled in machine shop classes and trade drafting classes and still others who are taking molding with a view to securing positions later on as part-time molders' apprentices.

"At the present time a new central trade school is being planned and it is intended that adequate provisions shall be made in the new building for such instruction in foundry work as will meet the needs of the industry as seen by the Pittsburgh Foundrymen's Association, working through its various committees.

"The Pittsburgh Foundrymen's Association has asked and received the cooperation of the Pittsburgh Public Schools in putting on an essay contest beginning in September of this year on the topic of 'Foundry Work as a Life Career.' The Association has offered substantial prizes for the winners of this contest and the details are to be worked out by a joint committee repre-

senting the Pittsburgh Foundrymen's Association and the Pittsburgh Public Schools."

From all of the above, it will be seen that while little has been done by the Pittsburgh Public Schools in the field of trade training for foundrymen, we are moving forward and are proceeding along the lines which are sure to take us in the right direction. A considerable expansion of this work is to be expected within the next four or five years, if the foundrymen themselves believe that such expansion is necessary or desirable for the interests of the trade.

The foundrymen are willing that all advancement possible be made and are helping at every point.

Co-operation First Essential Towards Success in Apprenticeship

By H. Jansen,* Moline, Illinois

Success in apprenticeship depends largely upon the proper attitude of mind. The most perfectly planned program of training can and will be made impossible as a reality unless the management of the organization committed to an industrial training program has the proper attitude of mind. In fact, it might be said that the latter will make an apprenticeship program successful without detailed plans. It is obvious that if this is a requisite in the individual plant or organization it becomes paramount in a community program where many organizations and groups must co-operate to make successful a community-wide plan of training.

What then can be said for the necessity of co-operation if five communities, located in two different states, join hands in a common plan of industrial education? Yet this is being accomplished in the five communities of Davenport and Bettendorf, Iowa, and Rock Island, Moline and East Moline, Illinois, formerly known as the Tri-Cities before Bettendorf and East Moline had been incorporated.

Here the co-operation, so essential in the individual plants, must not only be extended to each community, but the essential elements in the communities must join hands not only in the spirit of co-operation but also in the everyday reality where hard, harsh facts must be faced. The Tri-City Manufacturers' Association, formed when but three communities existed, along the Mississippi River represent some 67 different industries, varying in kind and product from foundries producing gray iron, steel and malleable castings, to clothing manufacturers producing male and female attire.

The co-operation of all plants representing a major industrial group was made possible only because of the splendid tradi-

*Executive Secretary, Tri-Cities Manufacturing Association.

tion built up through years of working together for a common object and purpose. It was only because a splendid confidence for the Association and its activities and program in the minds of the responsible heads of the member organizations that the apprenticeship training program, proposed scarcely more than a year and a half ago, was so completely, whole-heartedly and unanimously accepted by not only the personnel of the governing board, but also the individual organizations.

In a program of this kind, involving five communities in two different states, it is obvious that policies must be promulgated by a relatively few representative men and in a somewhat categorical manner. Without the confidence built up through years of working together, it would have been impossible to align towards a common end so many conflicting interests, parties, persons and organizations. Yet at the present moment, so far as foundry apprenticeship is concerned, 16 different foundries in five different communities, located in two states, are co-operating in the training of more than half a hundred foundry apprentices, who are scheduled to learn molding and coremaking through three and four year apprenticeships in gray iron, steel and malleable iron foundries.

These foundry apprentices, along with others representing seven different trades and totaling more than 125 at present, are attending school for their related class-room instruction in five different communities. In order to accomplish this, it was necessary to bring together five school boards and superintendents to unite on a common plan and program of action suited to an apprenticeship program of this nature. Even with a sincere willingness on the part of all concerned, the difficulties cannot be minimized. In the first place, when the varying laws and regulations of the individual communities, emphasized by the varying characteristics of the personnel in charge, are added to the complexities of two sets of state regulations, some idea of the necessity for not only co-operation in spirit but in actuality as well can be appreciated. In communities separated only by imaginary lines, apprentices live in one community and work in another. As a result it is necessary that they attend school in a community in which they have no legal residence. Yet co-operation can and did

overcome a problem of this kind, among many others. Secondly, one class-room supervisor or instructor was sufficient for the first few years. Thus it was necessary that three school boards and one state department of vocational education meet in serious but friendly conferences to adjust such matters as an equitable proportioning of salary. Finally, the finest spirit of co-operation is essential in the determination of such delicate questions as the administration of the school program in which one class-room supervisor taught apprentices in three different schools on a half dozen different days. Yet co-operation has and is triumphing over such difficulties.

Finally, in order that a common plan of action might be entered upon it was essential that two state departments of vocational education and five different school boards be drawn together. Co-operation alone could and did accomplish this task. In the actual working out of the program in everyday industrial life it was necessary, in this instance, that the spirit of co-operation, having its source in the Manufacturers' Association and its governing board and committees, must find its way down to the personnel administering apprenticeship in the individual plants.

When some of the organizations recently found themselves face to face with the necessity for seriously reducing their forces, it was determined, in the first place, that apprentices would remain, excepting in case of a complete shut-down. However, policies on paper and in action assume different aspects. To retain young apprentices while laying off married men who have been employed for a number of years or longer is obviously not calculated to maintain industrial morale at its proper level. Here again co-operation, so necessary in everyday affairs and details, came to the assistance of a particularly difficult problem. Not all plants were similarly affected by the depression. These latter were willing to have apprentices transferred to them from organizations where it was difficult not only to keep them at work but to maintain the morale while doing so.

The administrators of apprenticeship in the individual plants must be credited largely with not only fostering and developing the proper spirit of co-operation but actually displaying it when to do so meant the undertaking of disagreeable tasks.

Finally, this spirit of co-operation, which had its source in the efficient and intelligent personnel of the Tri-City Manufacturers' Association, has been spread and radiated out throughout the community so that parent-teachers and social and civic organizations are co-operating in the solution of this vital community problem.

To maintain an adequate supply of skilled personnel for the industries in these five communities, is but one of the problems that is receiving attention. To intelligently direct the young people of the community, from grade school, high school and college, into industry where a planned program of training, with proper supervision, awaits them is, if anything, a more vital problem for the entire community. To this end, all the elements have joined hands in the spirit of co-operation so splendidly exemplified in the original plan and dealings of the Tri-City Manufacturers' Association.

A brief two years' experience has shown that apprenticeship is not without its many difficult, grave and, at times, disagreeable problems. However, that they can be solved has also been proven. It would seem that the most vital essential to this end is co-operation. Individual plants and communities contemplating undertaking apprenticeship should not be dismayed if only they can be certain that the essential elements in the individual plants and communities can be brought together in the spirit of co-operation.

Upgrading of Foundry Apprentices

By C. Howard Ross,* East Moline, Illinois

Experience in the past has necessitated a training program in the following four directions:

1. Night school work.
2. Training foremen from the ranks.
3. Introduction of university leaders.
4. Apprenticeship training in the crafts by the upgrading method.

The first three plans must, of necessity, enter into this paper only from the discussion standpoint. We shall deal directly with item 4.

Earn and Learn Method

Under careful supervision and with proper human follow up we present the earn and learn method by means of which young men, exceeding 18 years of age and possessing the equivalent of an eighth grade education, may enter a craft training program and secure a livelihood in conjunction with mental progress.

The following items are of interest, when young men are introduced into plant activities, enabling their performance to be progressive:

1. Careful selection based on physical stability.
2. Accurate instruction.
3. Sincere and human follow up.
4. Pleasant surroundings, with special emphasis upon good factory housekeeping.
5. Dignity of the craft.
6. Ability to earn.
7. Inclination to learn.
8. Future usefulness.

An aggressive operation of the apprenticeship system, whereby men are able to earn and learn by the upgrading method, obtains best results when the right men are encouraged to stay and the unfit are deliberately eliminated.

*General Manager, The Union Malleable Iron Co.

During the highest peak, our school has consisted of the following personnel:

1 Director.
2 Instructing Foremen.
85 Apprentice Molders.
11 Coremaker Apprentices.
4 Pattern Maker Apprentices.

We are interested, at this time, in molder apprentices. They are introduced into the foundry at an arbitrary day rate of 40 cents per hour, which protects them over a two weeks' period. During this time, instructing foremen will initiate their experience with at least five short order jobs.

Upon termination of two weeks' primary activity with the five molding jobs completed, foundry apprentices are then placed upon a piece rate basis.

It has been our experience that the better quality of men, by their own efforts, can earn the equivalent of 35 to 40 cents per hour, during their third week. By the last day of their fourth week, 40 cents per hour has been secured without question.

The apprentice then faces the beginning of his fifth week as a $20.00 man. The better grade young men have been able to gain $1.00 per week for the next twenty weeks. Thus, in heavy production season, when tension is high, young men, exceeding 18 years of age, have been able to earn and learn consistently and some of the higher grade have drawn $40.00 per week at the termination of the first six months' period. These are special men, however, of good mental and physical caliber. Average apprentices of fair stability, with four to six months' experience, are able to draw about $100.00 per month.

Molding apprentices are classified on the following bases, indicating qualifications demanded in order to secure promotion from lower to intermediate and higher grades:

1. Class B:
   A. Inexperienced in foundry craft, but a fair subject for upgrading training over a six months' period.
   B. Eighth grade education.
   C. Minimum weight: 140 pounds.

D. Minimum height: 5 feet 8 inches.
E. Intelligence sufficiently evident to receive instructions.
F. Ambition to earn and learn.

2. Class A:
   A. Six months' experience.
   B. Twenty-five jobs.
   C. Scrap under 5 per cent.
   D. Earnings: $5.00 per day.
   E. Demonstrated mentality to absorb class room work.

3. Junior Journeymen:
   A. Twelve months' experience.
   B. Fifty jobs, of squeezer, bench, loose work and floor types.
   C. Scrap under 4 per cent.
   D. Earnings: $6.00 per day.
   E. Demonstrated mentality to absorb class room work.
   F. Amiable personal makeup with unquestionable ability leading to a future high-grade mechanic, with possible leanings toward an appointment on the supervisory force.

Special class room instruction is offered for the above groups, as follows:

(a) For Class "B" Apprentices, we recommend no class room instruction, but insist upon a mass meeting once a month for the presentation of policies, general encouragement and brief lectures.

(b) Class "A" Apprentices and Junior Journeymen will be enabled by their own choice to elect courses in the following subjects:
   1. Foundry engineering.
   2. Metallurgy.
   3. Shop arithmetic.
   4. Business economics.
   5. Industrial seminar.

4. Journeymen:

Any Class "A" or Class "B" Apprentice or Junior Journeyman, who has been allowed to remain on the job for three years and who warrants further employment, will be promoted to the rank of Journeyman Molder. It is possible, therefore, that a Class "B" Apprentice may effect a short cut from the lowest rank to the highest, but he will forfeit the right to his assignment of major jobs

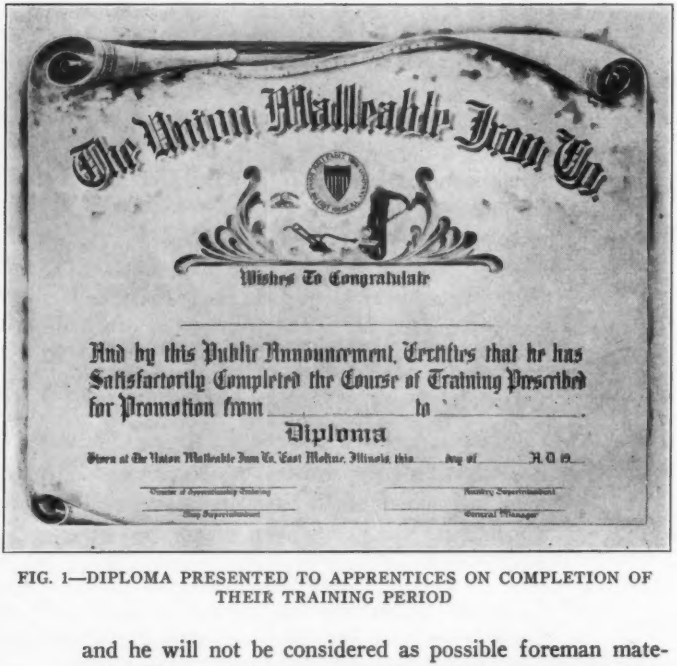

The Union Malleable Iron Co.
Wishes To Congratulate
And by this Public Announcement, Certifies that he has Satisfactorily Completed the Course of Training Prescribed for Promotion from _____ to _____.
Diploma
Given at The Union Malleable Iron Co. East Moline, Illinois, this _____ day of _____ A. D. 19_____
Director of Apprenticeship Training
Foundry Superintendent
Shop Superintendent
General Manager

FIG. 1—DIPLOMA PRESENTED TO APPRENTICES ON COMPLETION OF THEIR TRAINING PERIOD

and he will not be considered as possible foreman material. This forfeiture is not necessarily through any direct fault of a man, but through his inherited mediocre mentality.

Graduation exercises occur once or twice yearly, according to the situation that confronts us. Diplomas are presented, witnessed by the entire assembled personnel of the plant. Short

speeches of congratulation, encouragement and progressive outlook are offered by company officials. A word of instruction, comparing old and new methods of apprenticeship training, is generally rendered by a seasoned molder veteran, who is proud of thirty-three years' foundry experience. Acknowledgment is then rendered by a junior journeyman or newly created journeyman, who in the past has expressed in very acceptable terms the hopes, ambitions and appreciation of the graduating class.

The type of diploma used is illustrated in Fig. 1. All old English lettering, covering names, dates and ranks, are accomplished by one of our apprentices.

Class room and lecture work is gradually taking permanent form. Within a few years' time, we will probably be satisfied with it sufficiently to recommend it. To date, we have butchered our collected data considerably and will continue to do so until we are satisfied with it. In the meantime, we do not recommend it with any greater degree of alacrity than we would recommend a half-built house for occupancy.

For certain of our junior journeymen, we are employing correspondence school courses, which will have demonstrated their value within the next two years.

Within our program, we have no place for the 16 year old boy. We feel, however, that he has a proper niche in industry and other concerns have made room for him.

This paper merely outlines personnel classification by work to be accomplished.

Under the most careful craft instruction and deliberate follow up, the best selected material will dwindle to about 25 per cent of the initial figure within a year's time. We feel that 40 per cent would represent a very high salvage figure.

Certain enthusiasts in the apprenticeship business have announced, thunderously, that the main object of the apprenticeship school is to make men. They are apt to lay little or limited stress upon production demands. We believe there is much fallacy in such a one-sided opinion. By our earn and learn method, we hope, not only to make men, but castings with dignity of training and net profit of fabrication properly weighed and related.

Apprentice Training

CHAIRMAN H. A. FROMMELT: The apprentice training committee of the American Foundrymen's Association is principally an informative body. In other words, its activities are confined largely to the matter of promoting apprenticeship work. This promotional work in an Association of this kind takes place during the year at rather long intervals. Consequently the activities largely revolve around the committee members.

This committee has been active throughout the year, as best it can be under the circumstances, in attempting to promote apprentice training along foundry lines. They can be of assistance to you if you desire. They hold themselves open for this purpose. If you will communicate with R. E. Kennedy, the Technical Secretary, and lay your problems before him, he will suggest any one of these men to assist you, or if you suggest any committee member, he will be glad to place them in touch with you.

You have a great problem before you. There are only at present a few spots in the country where foundry apprentices are being trained. There should be many half dozens, many thousands, in the foundry industry. It is the biggest, most basic problem in the foundry industry at the present time.

This committee hopes that the work done during the past years, and particularly the results of the last year's work as shown by the program arranged for you, will be of some assistance and some help. Gentlemen, I will turn over the meeting to your Chairman of the Session, Mr. C. J. Freund.

C. J. Freund assumed the chair.

CHAIRMAN C. J. FREUND: The method of preparing this session was as follows: It was assumed, although not quite correctly that every foundryman realizes that apprentice training in principle is necessary to the foundry industry. We assumed, furthermore, that the reason why foundrymen were not universally establishing apprenticeship was because of certain difficulties that lay in the way. We circulated a questionnaire to find out precisely what those difficulties were. A large number of answers were received and this morning's program was based on those answers;

the people from those districts where apprentices have been trained successfully have been asked to show in their papers precisely how they overcame those difficulties.

Our first speaker this morning will be a gentleman who has been very active in the industry in Indiana Harbor in the furthering of what will be in time and probably is today, a very active apprenticeship program. Mr. F. A. Lorenz, Works Manager of the Indiana Harbor Plant of the American Steel Foundries, has been associated with Mr. Freeland in that territory. Mr. Lorenz will discuss apprenticeship in that locality.

F. A. LORENZ: My purpose here this morning is to try to place before you a background, if it may be termed such, of the educational program before the foundrymen.

There are a great many reasons why foundry apprenticeship has not been followed along lines which were already established perhaps 20 or 25 years ago. Since that period, as you all know, there has been a great revolution taking place in the foundry industry. In past years it was a question of hand work, individual patterns, individual molding by the shovel and tamping method, preparing molding sand by individuals.

During the intervening years the foundry industry has become highly specialized to a great degree. The introduction of the first crude molding machines and finally the molding machine coupled with the high capacity unit in a great many of the foundries has made for foundry specialists. There was an adequate supply of laborers or working men who could fill in the gap and take a specialized job and learn all there was to know about that job within a few weeks or a few months. That is one reason which to my mind caused apprentice training to be dropped. We had plentiful immigration, we could get men. The foundries did not consider the cost of "breaking in" a man, until we find ourselves today with a rising average age limit in the foundry industry and an ever decreasing number of men who are capable of all-round foundry work.

Apprentice training is part of a general educational program. It seems to me we should not confine ourselves to the one proposition of apprentice training. We should rather look ahead to the available sources of material for foundrymen. I should say that

up to the present time, in the activities following the War, there was great stress laid by all the educational bodies towards training of foremen. Perhaps too much stress was laid on the training of foremen, which has caused a great many of the industries, not only foundries, to start and train from the top. Foremen training is already well established. Manufacturers took the cream of their organization and started in to train them. The organization was already well seasoned. They were well trained, they knew their job, and still we went to work on them and instilled into them the principles of industry in order to get them to pass it along down the line to the men under them.

In a great many cases it has met with success, but I would think in more cases it has been a failure because of the lack of teaching ability of these already seasoned supervisory organizations. Gradually we have come around to study the situation until we realize that we have as our sources of material for training our great school system. Our compulsory education system gives us as a basis the 16 year old boy, at which age he can enter training of any kind. Beyond this we have the high school, and then the college.

Naturally the foundry group is an industrial group and relies on the technically trained men, therefore the necessity of our educational programs. It seems to me we should provide for the education of the common school boy, the high school boy, and the technically trained college man as well. These groups are so interallied, it is felt necessary that an apprentice training program should embody the machinery necessary to train these into the foundry industry.

In talking with some of the gentlemen before this meeting, it occurred to me that most of the men here were here because they were interested in apprentice training. In talking to a great many of the men who have been at the front in this fight for apprentice training, their stories all seem to agree that in principle the question of apprentice training is accepted, but in actuality when it comes to instituting the programs in already going concerns or in the foundry, they meet with a sort of doubtful attitude on the part of the executives.

The first question naturally is, will it pay? The next question is, how are we going about it? All these things I think are

ably answered in these papers. It is not my purpose to try to get into the detail of how it is to be done, but there are certain things that are outstanding and in the foreground of apprentice training. One of the biggest objections has been on the part of people—whether it is a thinking one or knowing one or not is a question—but there is a distinct feeling that young America of today is not interested in the foundry industry, largely because of the conditions of work which naturally must surround it. Whether that is true or not remains to be seen by the actual working out of the foundry apprentice program.

But we have a bigger job than that. It is the job of the industry to so prepare the minds of the educators of the United States and the boys below them and to instill in them the right attitude of mind towards the so-called industrial job.

It seems to me there is a great background which we have to prepare before these foundry training courses can become actualities. If we are to prepare a foundry apprentice course, we must realize certain basic things, that the question of skill is simply a matter of training. You are not born with skill, the average man is not born with it, it is simply and basicly a matter of training. After we have trained our men we have the largest available material within our own plants for training our executives.

In making our surveys of the educational programs in our district, we have found that we are confronted with compensation laws, which make it very difficult for us to employ minors or boys under the age of 18 years. That is one of the things which has to be worked on from a legislative standpoint. If you go to your lawyers they will tell you that you are accepting hazards to take boys into your employ under a certain age. In spite of that the companies are training boys from 16 years upward and are not experiencing any great difficulty with it.

Turnover figures are referred to in one of the papers. The question of training men may be looked on this way, and it is one of the basic points for a general educational program which foundries are undertaking. It has probably been your experience that a young man has received training in another industry under entirely different conditions and for some reason or other he

applies to your company for work. The change in surroundings are so great, that while he may be a very good man, yet on account of certain physical conditions in the foundry he will not stick. That has a great deal to do with a man's staying on the job. But if you get a man young enough he can get used to anything. If you can train them into your job and have them become used to the foundry conditions, and keep them there three or four years, that man usually remains a loyal employee. A man who is satisfied with his job and is willing to work in a foundry will be loyal in the company and you can develop him.

But in order to do this you must have some organized, well defined method of training. You must have something to offer to your prospective apprentice. You must satisfy him and you must satisfy his parents of the real intentions of the company and show by actual experience that you intend to carry them out. After all the thing resolves itself down to the best way of training apprentices and a well organized method for so doing.

Most of the companies that have gone into this, at least according to our surveys, have stated, that where there has been a careful supervision, and a carefully organized course, that it was certainly worth the price it has cost them to undertake such training. Apprenticeship is an actuality in a great many cases, in a great many cities, and in a great many trades besides the foundry trades. Unfortunately our industry has been one of the slowest to adopt apprentice training.

There are under way apprentice programs in Betendorf, Ia., Davenport, Ia., Moline, Ill., East Moline, Ill., Hartford, Conn., Portland, Ore., Bay City, Mich., and the City of East Chicago, Ind. These are just a few of the cities that have foundry apprentice training courses in preparation or in actual working order. We realized in East Chicago that if one or two foundries went into apprentice training they would be the pioneers, so we stretched out to embrace every industry in the Calumet district. There is a committee under the auspices of the Chamber of Commerce and the Manufacturers' Association and it looks very promising.

CHAIRMAN C. J. FREUND: Mr. Lorenz has clearly explained the history of apprentice training or of training of all kinds in

the foundry industry, and has laid down, and described general conditions as they exist at present. Mr. Lorenz's paper is the foundation of our program.

The next speaker is a gentleman who, I think, is a rather unique individual. The manufacturers often do not take the school people too seriously in matters other than purely educational and vice versa, the school people sometimes think the manufacturers are all wrong. However, it is usually a question of lack of cooperation. The speaker whom I wish to introduce has a remarkable school, and at the same time is chairman of the Manufacturers' Committee on apprenticeship of Harvey, Ill. Gentlemen, I take pleasure in introducing Mr. George Hayes, Director of Vocational Education, Thornton Township High School, Harvey, Illinois, who will speak on the subject, "A Real Training Program Destroys Prejudice."

G. HAYES: I had the privilege and pleasure of being with you in Detroit last September. I said a few things there and about the only thing I have to say today would be a reiteration of what I said in Detroit at that meeting.

I think in a program of apprentice training that the public school has a part, no matter where it is. And so far as I have been able to find out, I am the only representative from any public school at this meeting today.

At the present time we have in training in Harvey 85 apprentice boys. Twenty of those boys are in the foundry. That is not a very large number, but we started this work just one year ago and we started with nothing. This week one plant, the Whiting Corporation, is adding seven apprentice boys to their foundry list. I rode up here today with their employment manager and he informed me of that fact.

We are growing all the time and will have within the next two years some 150 or 175 apprentice boys in training. These boys come to school for eight hours a week. And each of them studies work which is directly related to the work he does on the job. In addition to that he studies mathematics in some form, which may be anywhere from fifth grade arithmetic on up to the study of calculus or trigonometry. Thirty-five of our 85 boys are high school graduates, 30 more of them have had some high

school work, and the rest of them with but one or two exceptions are graduates of 8th grade.

Our program is unique because we are a small community, and our apprentice training program is represented in nine plants. We have two plants which are not carrying any apprentices as yet, but we have hopes that soon they will.

One thing I have noticed in talking with the men in this group before this meeting is that everybody here is particularly interested in training apprentices, boys. And with but very few exceptions in this group, I believe we are all actually doing the work.

I should like very much to have the privilege of being in a group like this where the vice-presidents and the general managers and works managers of the plants you men represent would be present.

I was asked to say something this morning about whether or not we have any difficulty in getting enough boys to take apprentice jobs. I received one of the questionnaires sent out by Mr. Freund's committee. On that questionnaire a number of questions were asked relative to whether or not boys are interested in taking up the work. Well, we have 85 apprentice boys working and I think we have fully three applicants for every one of those jobs. And that condition continues to exist.

We have set up quite a program in our high school to feed the apprentice supply in the plants. Ours is an industrial community and not a large number of our high school students get to college. We are graduating this year 120 students from our high school, more than half of which are boys. And as far as I have been able to find out we don't have places for more than 15 of those boys in the manufacturing plants.

We have one plant in our group that is notable in the success which it is making of the apprentice work. And I want to mention that plant and tell why I think their work is going along a little more smoothly and why they are accomplishing a little bit more than the average plant, and that is the Whiting Corporation.

They started just a little over a year ago without any apprentice boys and they now have 35. This week they are going to add seven foundry apprentices to their group. I think those

boys, in fact, I know those boys have an attitude toward that concern that is going to lead them until some day a good many of those boys are going to have a word to say about running that institution. The reason that this is possible is because from the president clear down to the last employee, as near as I have been able to find, everybody in the plant is boosting for the apprentice group. I think that is absolutely necessary before an apprentice training plan can function. I don't believe it can function if the man in the top office sits up there and says, "Apprentice training is fine," and then forgets it. That has happened in several instances in our group and I don't like to tell the other side of it, but where that has happened results have not been so favorable.

There is one other thing I would like to call attention to and that is the school teacher. I fully agree with everything the first speaker on the program had to say about them. They have a tendency to want to study Greek, Latin, English, Keats, Shelly, etc., but there is a limited group within the school teaching group who are trying to help make a connection with industry.

The American Vocational Association had their first convention at Louisville, Kentucky, this last year in December. At that meeting there were about 3,000 people, and half of those people were from schools and about half of them were from industries. And I think the answer to the apprentice training problem is that the school teachers and the industrial people must get together to make apprentice training function.

Now the next meeting of the American Vocational Association is in Los Angeles next December. I should like to suggest and propose to this group that the American Foundrymen's Association be represented there officially. I think by all means it should be. I am speaking from the standpoint of the school man.

I said last year in Detroit and I want to say again that I believe the public school can function in the training of apprentices, and I believe that wherever there are apprentices to be trained you will find the school people receptive to any proposition that has to do with the giving of any kind of cooperation. I would like to throw that out as a challenge to you. Any man from any industry who wants to train apprentices can make a hook-up with his local school most anywhere.

The remaining papers presented at this meeting were preprinted and are republished and will be found on pages 45 to 83 of this volume. The discussion of these papers was as follows:

Discussion

Chairman C. J. Freund: To one who should casually pick up one of these booklets and look at it, it would simply be a collection of papers and not much else. He might be interested in some of the subjects, but that is about all. However, in looking at it from another angle, we have here a collection of papers prepared by men who are actually at work in one way or another in the foundry industry.

As the papers have been read, undoubtedly many thoughts have come to the minds of the people present. The meeting is now open for discussion. We should like to have the discussion opened, if we may, by the Director of Apprenticeship of the Industrial Commission of Wisconsin. Apprenticeship in Wisconsin is under the supervision of the State, the Industrial Commission, and the Commission employs a considerable number of full time apprentice supervisors and clerks and the chief of these is Mr. Walter Simon, who has been engaged in apprentice work of some kind or other for a number of years and is himself an apprentice graduate.

The Industrial Commission is not only interested in metal manufacturing apprenticeships, but has gone so far as to establish apprenticeships in the grocery business, in the shoe business, and in many different occupations. There are about 3,000 apprentices in Wisconsin under the supervision of the Industrial Commission.

W. Simon: We have developed apprenticeship in a great many industries and businesses in Wisconsin, there is no doubt, but we find our hardest problem is to get the employer interested to the point where he will hire apprentices and take interest in the boy after he hires him. There are very few employers who have apprentices who are sold on apprenticeship as they should be sold to it. I should say that not more than five out of a hundred are as deeply interested in it as they should be.

I was talking to one of those men the other day and he was telling me about a boy he had in his plant whom he would like to get rid of. He said, "He is a good boy personally, but he will never make a first class mechanic, but I don't want to fire him, because you can't tell what is going to happen to him; he might come out well in some other place and make me feel pretty foolish. So I am just going to keep him on the job. I would feel like two cents if he left here and went somewhere else and turned out to be a crackerjack of a mechanic."

That is what happens in a great many cases. So it is with a lot of apprentices. They seem to be failures at times, but many later develop into good men in time.

I think we could get more out of the remaining portion of the meeting through a discussion. You men have listened to talk all morning and I think if you would ask these gentlemen some questions you would get a lot more out of it.

F. A. LORENZ: What are the compensation laws regarding the hiring of 16 year old boys in Wisconsin? How do the employers get around that law?

W. SIMON: There are only two or three that I can think of which affect boys 16 years of age, such as the laws about high tension wires, for example, in the electrical trade, or working around explosives, that is about all.

F. A. LORENZ: Are there any other occupations which might be hazardous?

W. SIMON: Oh, yes, but no employer hesitates to hire a lad 16 years of age. I think it would be a mistake to discourage the hiring of 16 year old boys, for they would be spoiled before they are 18 years of age. They would be spoiled for apprenticeship work or anything else.

H. J. ROESCH: Mr. Simon, with regard to the law concerning grinders and overhead cranes, and such as that, hasn't that been changed recently or amended to except apprentice boys?

W. SIMON: Yes, that has been amended to except apprentice boys.

F. A. LORENZ: I wanted to bring that out and settle it in the minds of a great many people on the question of hiring minors. They go to their law firm and they come back with a big, long brief on the subject and it scares them to death. We in our company overruled the casualty department on that situation unanimously through the works end of it, realizing that compulsory education kept the boy from the time he was 16 to 18 out of work. Therefore, he had a two year period in which to do nothing, which was a very serious proposition to the community. It is a serious proposition to handle these boys for those two years, for they are getting into mischief, and yet they cannot be hired under the law. But you must simply go ahead and take the thing up through your legislature and try to correct it. You have there a juvenile delinquency problem which is bad. We have gone right ahead in Indiana in the hiring of these boys.

W. SIMON: Yes, I can see where the only cure for that problem is to get it remedied through legislative channels.

MR. MONTGOMERY: I have only been in the foundry about two years, but I rise in reference to that foreman and the boy in the foundry mentioned by Mr. Simon. Wouldn't you think the foreman did the wrong thing? Whenever a young fellow gets so his work is unsatisfactory, he needs to be kicked out, and then he gets a new job and it does him some good. If he doesn't get kicked out he stays there loafing along doing no good. But if he gets kicked out it may give him a spur to go ahead and do something better.

MR. MEYER: I don't quite agree with the gentleman who just made the statement to fire the boy simply because he wasn't interested in the foundry department or one particular game and wasn't giving results. Instead, I think we might dig into him and find out just exactly what he was interested in. I think it would be possible and better to change that boy or apprentice into another branch. After you have gone to the expense and time of training the apprentice, if he does you no good in that particular department, I believe you should put him in some other department, or ask him where he would prefer to go. I believe that would help, instead of adding him to your labor turnover. Our labor turnover runs up the cost just as much as anything else.

G. OLSON: In the first place, I would say in regard to that foreman, he should have said to himself, Am I doing all I can or all I ought to do in respect to this youngster of mine? Oftentimes a young man starts dragging along on the job, not knowing what is holding him back. It may not be a lack of interest, it may be something else. So, first of all, he should go and have a personal talk with the youngster just to get under his skin and learn what is ailing him. I have found in our plant that is the right procedure to take.

We have a youngster who has been with us for some time. He started off very well, showed himself to be full of pep, and we had good hopes. After six months he rather fell down. And my understudy came in reporting, "That fellow, So and So, is no good. I would like to have him discharged."

I said, "Well, what is the matter with him?"

And he didn't have any particular reason for discharging him only that he was no good. And if I had been the kind that some men are, I would have said to my understudy, "Go down and pay him off." But I never let that happen. Always, when it comes to the last straw, I go down myself to just see and learn from the young man what he is up against. Probably he has a job he doesn't quite understand and he may be having trouble.

I know we had a boy last year also who had been on the job about four or five months and didn't make good and he was given the second job. He couldn't handle that. Well, the boss fought with him for a while and then gave him the third job, and as a result my understudy said he would like to get rid of him. And I said, "First of all, I would like to see what he is up against." So I made a molder out of that boy, the very thing which my understudy said he couldn't do.

Those are just a few points to look into. You can give him a kick and fire him out and sometimes that might work out, but we have all been boys and have all gone through the mill. I dug sand for a good many years, and I got my kicks and learning right on the job. But we are more human now days. And I think it is only right that we should give the young man a good chance.

Joint Committee on Pattern Equipment Standardization

The Joint Committee on Pattern Equipment Standardization following its issuing of the standards of pattern and core box color markings considered other practices in this field. At its recent meeting the policy of issuing recommended practices in preference to standard practices was adopted, although it was considered that certain practices or designs might be best issued as tentative standards or standards.

Below are listed recommended practices which have been approved for adoption by foundrymen. Tentative standards of vibrator designs are also listed. The joint committee sponsored by the American Foundrymen's Association is composed of representatives of the following organizations:

American Foundrymen's Association
American Society for Testing Materials
National Association of Purchasing Agents.
Electric Steel Founders' Research Group
Foundry Equipment Manufacturers' Association
American Malleable Castings Association
Steel Founders' Society of America.

Three sub-committees have been organized as follows:

Sub-Committee on Pattern Making.
Sub-Committee on Pattern Mounting
Sub-Committee on Flask Sizes.

The standard pattern and core box color marking has been given wide distribution and it is hoped the additional tentative standards and recommended practices listed here will be given careful consideration. The committee would like to have further suggestions for recommended practices submitted to it by anyone interested in this line of endeavor.

D. M. Avey, *Chairman,*
Joint Committee on Pattern
Equipment Standardization.

Recommended Practices

1. Marking gaged surfaces and locating points on patterns:

(a) The committee approves as a recommended practice, supplementary to its standard pattern color markings that:

When casting surfaces are to be accurately gaged, though not machined, that the gaged surfaces or points be indicated by distinctive markings, such as by painting a special color or inserting a metal disc, care being taken so that the marking will not interfere with the pattern draw.

(b) Further, the committee approves as a recommended practice that locating points for machining operations be indicated, on the pattern by distinctive markings such as a color or metal disc insert, providing that the marking will not interfere with the pattern draw.

(c) Further, the committee approves as a recommended practice that both gaged surfaces and machining locating points of castings be shown on the blueprints and that, wherever practical, locating points shall not appear on cored surfaces.

2. Markings indicating chilled surfaces and metal inserts on patterns:

The committee approves as a recommended practice that when internal chills or metal inserts are necessary that the word "chill" or "metal insert" be stamped on the place to be chilled, or on the prints of the metal insert.

3. Color ingredients of coating materials for marking patterns:

The committee approves as a recommended practice that when patterns are to be painted according to the committee's approved standard color scheme, that the paints or shellacs to secure the standard color markings may be obtained by a medium vermillion red powder with white shellace for the red color, and a pale yellow ochre mixed with ordinary yellow or white shellace for the yellow color.

4. Pattern Letters:

The committee approves as a recommended practice that pattern letters best suited for steel and brass castings are the

round faced or flat faced gothic pattern letters; pattern letters best suited for gray iron and aluminum castings are the sharp-faced or hair line pattern letters.

5. Loose pieces for pattern and core boxes:

The committee approves as a recommended practice that all loose pieces for patterns and cores, and the prints for the loose pieces on the patterns and core boxes be marked consecutively so that a No. 1 loose piece will fit a No. 1 print, a No. 2 loose piece will fit a No. 2 print, etc.; further that when right and left loose pieces are called for that the print be stamped "R or L" and the letters R and L be stamped on the respective loose pieces; further, as a factor of safety, it is recommended that the pattern maker use one small and one large dowel pin in order to eliminate the danger of loose pieces being reversed.

6. Leather fillets:

The committee approves as a recommended practice the use of fillet sizes as given in the schedule of Table 1.

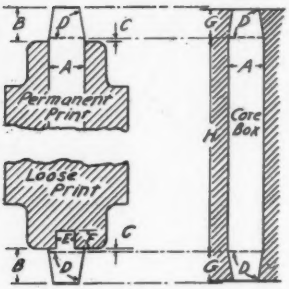
FILLETS—PREFERRED SIZES FOR CASTINGS

Thickness of Wall, Inches	Material of Casting	Thickness of Wall, Inches							
		Up to 1/8	Above 1/8 to 1/4	Above 1/4 to 3/8	Above 3/8 to 1/2	Above 1/2 to 5/8	Above 5/8 to 3/4	Above 3/4 to 7/8	Above 7/8 to 1
Up to 1/8	Iron and Steel	1/4	..	3/8	3/8	3/8	1/2	1/2	5/8
	Malleable Iron	1/8	..	1/4	1/4	3/8	3/8	1/2	1/2
	Copper and Alloys	1/4	..	3/8	3/8	3/8	1/2	1/2	5/8
Above 1/8 to 1/4	Iron and Steel	3/8	3/8	..	3/8	1/2	1/2	5/8	5/8
	Malleable Iron	1/8	1/4	..	3/8	3/8	1/2	1/2	5/8
	Copper and Alloys	3/8	3/8	..	3/8	1/2	1/2	3/8	3/8
Above 1/4 to 3/8	Iron and Steel	3/8	3/8	3/8	..	1/2	5/8	5/8	3/4
	Malleable Iron	1/4	1/4	3/8	..	1/2	1/2	3/8	5/8
	Copper and Alloys	3/8	3/8	3/8	..	1/2	3/8	3/8	3/8
Above 3/8 to 1/2	Iron and Steel	3/8	3/8	1/2	1/2	..	3/8	3/4	3/4
	Malleable Iron	1/4	3/8	3/8	1/2	..	3/8	3/8	3/4
	Copper and Alloys	3/8	3/8	1/2	1/2	..	3/8	3/8	3/8
Above 1/2 to 5/8	ALL	3/8	1/2	1/2	5/8	5/8	..	3/4	3/4
Above 5/8 to 3/4	ALL	1/2	1/2	5/8	5/8	3/4	3/4	..	3/4
Above 3/4 to 7/8	ALL	1/2	5/8	5/8	3/4	3/4	3/4	1	..
Above 7/8 to 1	ALL	5/8	5/8	3/4	3/4	3/4	1	1	1

7. Core prints for metal patterns:

The committee approves as a recommended practice for use in determining the size and shape of core prints for metal patterns, the design and sizes shown in Fig. 1.

Sizes of Core Prints



Note.

It is essential that cope and drag prints are identical and that the dimension "H" in both corebox and print correspond When dimension "H" is increased, "G" should also be increased proportionately.

Note the difference in overall length of corebox and prints.

A	B	C	D	E	F	G	H
3/16	17/64	1/32	88°	1/8	3/16	15/64	1 1/2
7/32	19/64	1/32	88°	1/8	3/16	17/64	1 1/2
1/4	21/64	1/32	85°	1/8	3/16	19/64	1 3/4
9/32	23/64	1/32	85°	1/8	3/16	21/64	1 3/4
5/16	25/64	1/32	85°	3/16	3/16	23/64	2
11/32	27/64	1/32	85°	3/16	3/16	25/64	2
3/8	15/32	3/64	85°	3/16	5/16	27/64	2 1/2
13/32	1/2	3/64	81°	3/16	3/16	29/64	2 1/2
7/16	17/32	3/64	81°	1/4	1/4	31/64	2 3/4
15/32	17/32	3/64	81°	1/4	1/4	31/64	2 3/4
1/2	17/32	3/64	81°	1/4	1/4	31/64	3
17/32	9/16	3/64	81°	1/4	1/4	33/64	3
9/16	9/16	3/64	81°	1/4	1/4	33/64	3
19/32	37/64	3/64	76°	3/8	1/4	17/32	4
5/8	19/32	1/16	76°	3/8	1/4	17/32	4

A	B	C	D	E	F	G	H
21/32	5/8	1/16	76°	3/8	3/8	9/16	4
11/16	5/8	1/16	76°	3/8	3/8	9/16	4
23/32	21/32	1/16	76°	3/8	3/8	19/32	4
3/4	21/32	1/16	76°	3/8	3/8	19/32	4
13/16	23/32	1/16	76°	3/8	3/8	21/32	5
7/8	25/32	1/16	76°	3/8	3/8	23/32	5
15/16	25/32	1/16	76°	3/8	3/8	23/32	5
1	25/32	5/64	76°	3/8	3/8	25/32	5
1 to 1 1/4	29/64	5/64	76°	1/2	1/2	27/32	6
1 1/4 to 1 1/2	1 1/16	3/32	76°	1/2	1/2	31/32	6
1 1/2 to 1 3/4	1 5/32	3/32	76°	1/2	1/2	1 1/16	6
1 3/4 to 2	1 19/64	7/64	76°	1/2	1/2	1 3/16	6
2 to 2 1/2	1 7/16	1/8	76°	3/4	5/8	1 5/16	8
2 1/2 to 3	1 9/16	1/8	76°	3/4	5/8	1 7/16	8
3 to 4	1 13/16	1/8	76°	1	3/4	1 11/16	10

FIG. 1

8. Lug design for match plate:

The committee approves as a recommended practice the use of lugs on match plates of the design shown in Fig. 2.

9. Position of vibrator bolt holes in match plates:

The committee approves as a recommended practice the placing of vibrator bolt holes in match plates according to the positions shown in Fig. 2.

10. Pattern plate thickness:

The committee approves as a recommended practice the use of flat aluminum pattern plates of a thickness of ⅜" for plates which are used with flasks 12" by 20" or less in size and of a thickness of ½" when used with flasks over 12" by 20" in size.

Tentatively Adopted Standards

1. Design of vibrators for match plates. (Applying to vibrators up to and including ¾" in size.)

(a) Size of hole for fastening vibrator to pattern plate.

The committee approves as a tentative standard the use of a 5/16" inch diameter hole in vibrators.

(b) Location of bolt hole in vibrators.

The committee approves as a tentative standard for vibrators for match plates a design which calls for space of 9/16 inch from the center of the vibrator bolt hole to the pattern plate shoulder of the vibrator. (See Fig. 2.)

(c) Shape of pattern plate end of vibrators.

The committee approves as a tentative standard the design of vibrators which specifies that the patterns plate end of the vibrator shall be rounded. (See Fig. 2.)

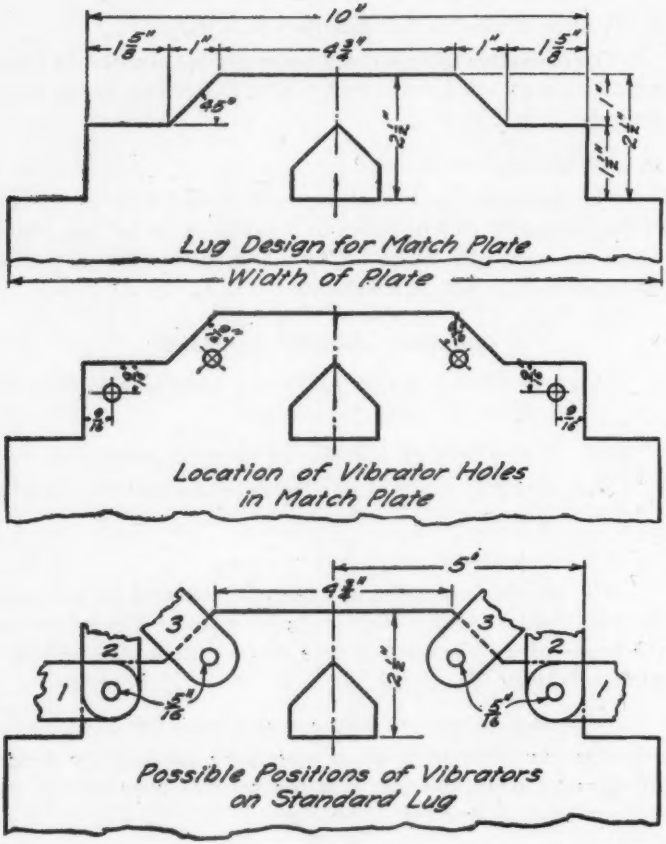

10"
1 5/8"
1"
4 3/4"
1"
1 5/8"
45°
2 1/2"
1"
2 1/4"
1 1/2"
Lug Design for Match Plate
Width of Plate
Location of Vibrator Holes
in Match Plate
5"
4 3/4"
3
2
1
2 1/2"
5/16"
Possible Positions of Vibrators
on Standard Lug

FIG. 2

Bureau of Standards Soil Corrosion Investigation*

Second Progress Report on Unprotected Pipe

By K. H. Logan,† Washington, D. C.

I. *Introduction*

1. *Nature of the Investigation.* In 1922, as a result of its electrolysis studies, the Bureau of Standards, Department of Commerce, in cooperation with the Department of Agriculture and a number of pipe manufacturers and public utilities, undertook an investigation of the relation of soils to corrosion, the primary purpose of which was to ascertain the extent to which soil action might account for observed deterioration of buried pipes.

In order to make the data generally applicable it was deemed essential to study soil action on the various kinds of pipe material in common use, but the primary purpose of the undertaking was to secure data on the corrosiveness of soils rather than to compare the merits of materials.

It was hoped that in case soil corrosion was found serious the data would form the basis for determining the causes of soil corrosion, for establishing methods of predetermining the corrosiveness of soils and for specifying means of protecting pipe from soil action.

2. *Cooperation and Materials in 1924 Examination.* The proposed investigation attracted wide attention, and the scope of the work was widened from time to time at the request of cooperating organizations to include a number of materials and conditions not originally considered. At present there are about 90 organizations cooperating in the work and approximately 14,000 specimens have been buried, of which some 2,000 have been removed for examination.

*Published by permission of the Director of the National Bureau of Standards of the U. S. Department of Commerce.

†Electrical Engineer with Bureau of Standards.

The materials under test include 20 varieties of bare iron and steel pipe, 24 varieties of bare non-ferrous metal, 17 kinds of bituminous coatings applied to pipes, galvanized material with 6 weights of coatings, and two kinds of aluminum and lead coated pipe. Forty-seven typical soil conditions selected or approved by the Bureau of Soils of the Department of Agriculture are under observation.

A detailed statement as of 1924 of the cooperating organizations, materials involved, soils selected, and methods of burying the specimens is contained in the 1924 Transactions of the American Foundrymen's Association.[1]

3. *Additional Cooperation and Materials, 1926.* To the 1924 cooperating organizations should be added:

The Cast Iron Pipe Publicity Bureau.*
The American Foundrymen's Association.*
The American Gas Association.*
The American Water Works Association.*
The American Petroleum Institute.*
The American Society for Testing Materials.*
The American Engineering Standards Committee.*
The American Zinc Institute.*
The New Jersey Zinc Company.*
The Rochester Gas & Electric Company.
Armco Culvert & Flume Mfg. Association.*
The Asphalt Association.*
The California Gas Research Council.
The American Brass Co.
The Locomotive Terminal Improvement Co.
The Paraffin Companies.
W. H. Kobbe.

Water Resources Div., U. S. Geological Survey, Dept. of Interior.

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[1]Trans. of the American Foundrymen's Assoc., vol. XXXII, pp. 144-166.
*Sent representatives to grade specimens and advise as to reports thereon.

The Aluminum Company of America.*
The American Sheet & Tin Plate Co.*
The American Zinc Products Co.*
The Bridgeport Brass Co.*
The Hoyt Metals Co.*
U. T. Hungerford Brass & Copper Co.*
Illinois Zinc Co.*
Lumen Bearing Co.*
National Lead Co.*

Additional materials were buried in 1926 as follows:

1. Lead coated pipe (new process).
2. Chromium iron tube.
3. Steel and wrought iron pipe with oxide removed by grinding (to determine effect of oxide on pitting).
4. Asphalt impregnated cloth pipe wrapping.
5. Sulphur impregnated cloth pipe wrapping.
6. Copper pipe (3 kinds).
7. Brass forgings.
8. Brass pipe (red brass and Muntz metal).
9. Aluminum bronze rod.
10. Nickel copper alloy rod.
11. Cast iron pipe with A. W. W. A. specification coating.
12. A number of lead alloys (for the Bell Telephone Labs.).
13. Additional specimens of asphalt impregnated cotton cloth pipe wrapping.

Most of the above specimens were buried in only six soils.

II. *Summary of Results in the First Progress Report on Soil Corrosion, 1924*

In order that the progress of the soil action could be noted and a rough idea gained as to possible results of the investigation, some specimens buried in 1922 were removed from each location

* Furnished specimens through the U. S. Bureau of Mines.

in the fall of 1923 and the following spring, and the conclusions drawn from the examination of these specimens embodied in the report presented at the meeting of the American Foundrymen's Association previously referred to. Briefly, these results showed that the welded iron and steel pipes buried in any one of the test locations differed little in the extent of pitting or in the loss of metal per unit of exposed area and that severe pitting and serious loss of metal had occurred in several soils.

The corrosion of the cast iron differed somewhat from that of the welded metal, but it also showed serious pitting in a few locations. Where the pitting of the cast iron was severe the corrosion product was always of the type commonly referred to as graphitic. This corrosion product could not be removed by washing and brushing as usually can most of the corrosion products of steel, but had to be dug out with a knife or sharp tool. The pits' boundaries were frequently indefinite and the corrosion products became harder on long exposure to the air.

The type of corrosion differed widely in different soils. In very wet corrosive soils and in the alkali soils the corrosion occurred in patches, sometimes as large as the palm of the hand; in the heavy clay and silty soils the corrosion usually took the form of rather small deep pits; in one sandy soil the specimens appeared as if worm eaten, while in a single very wet silt loam the oxide was removed as if by acid pickle, but the iron beneath showed little corrosion and no pits. In one well-drained gravelly soil almost no corrosion was found. From these results it was concluded that the initial corrosion of the commoner kinds of pipe depended upon the character of the soil rather than that of the pipe material.

The data now available seem to indicate that soil corrosion is largely a problem of soil physics or chemistry.

III. *Results of Examination of Unprotected Pipe Specimens Removed in 1926*

1. *Grouping of Specimens for the Report.* When specimens were removed in 1924, specimens of additional materials were buried, some in all locations, others in only six soils. Samples

of these materials were removed along with the unprotected specimens in 1926. An idea of the number of specimens removed may be had from Fig. 1, which shows the unprotected specimens, and Fig. 2, which shows the specimens of galvanizing and bituminous coatings. In addition to these there were removed about 800 specimens of miscellaneous materials.

FIG. 1—UNPROTECTED SPECIMENS, 1926

FIG. 2—SPECIMENS OF PROTECTIVE COATINGS—GALVANIZED SHEET AND PIPE AND BITUMEN COATED PIPE

The number and diversity of the samples makes it advisable to divide them into classes and to present a separate report on each class.

A report on the bituminous protective coatings was presented at the joint corrosion symposium of the American Society of Mechanical Engineers and the American Petroleum Institute

in Tulsa, Okla., December 9, 1926. A report on soil action on galvanized iron and steel is in preparation and a report on soil corrosion of non-ferrous material is contemplated. This report deals only with the unprotected pipe specimens such as were reported on at the 1924 meeting of the American Foundrymen's Association.[2]

2. *Notes on Protective Coatings.* In passing, it might be well to mention very briefly the results of the examinations of other classes of specimens.

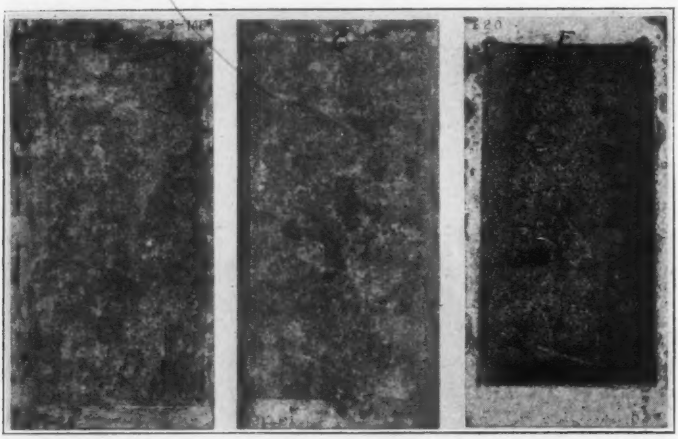

FIG. 3—TYPES OF CORROSION OF GALVANIZED SHEETS—RATINGS: E, EXCELLENT; G, GOOD; F, FAIR

In general, the rate of corrosion of the galvanized sheet and pipe varies widely with the soil condition. In most soils the alloy layer appears to have been reached in spots, but the base metal has not been exposed. In a few locations the base metal has been reached, and in two or three soils the sheet specimens are rather badly corroded. Figs. 3 and 4 show typical specimens of the galvanized sheets with approximately 2 oz. coatings. They were buried about 2 years. After the galvanized pipe specimens

[2] Trans. Am. Foundrymen's Assoc., vol. XXXII, pp. 144-166.

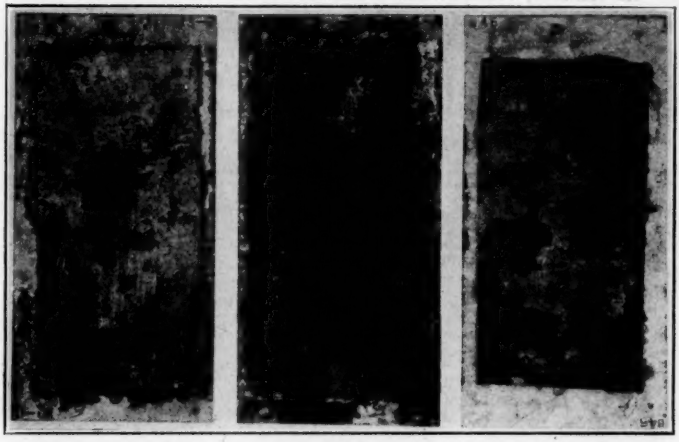

FIG. 4—TYPES OF CORROSION OF GALVANIZED SHEETS—RATINGS: S, STRIPPED; R, RUSTED; P, PITTED

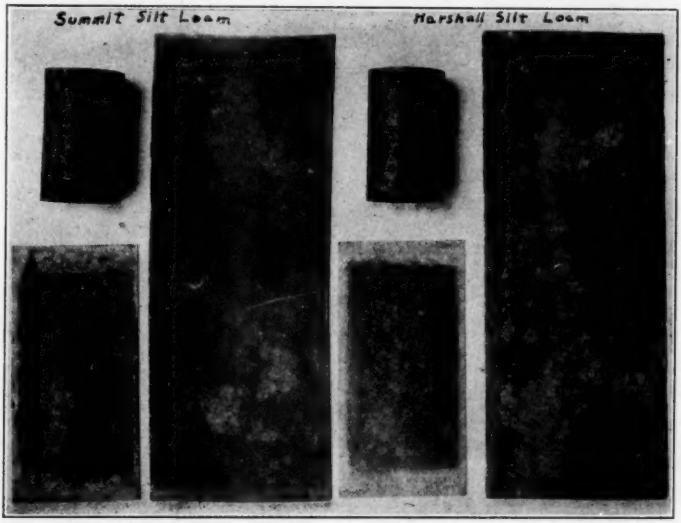

FIG. 5—STEEL PIPE, GALVANIZED IRON AND LEAD SHEATHS

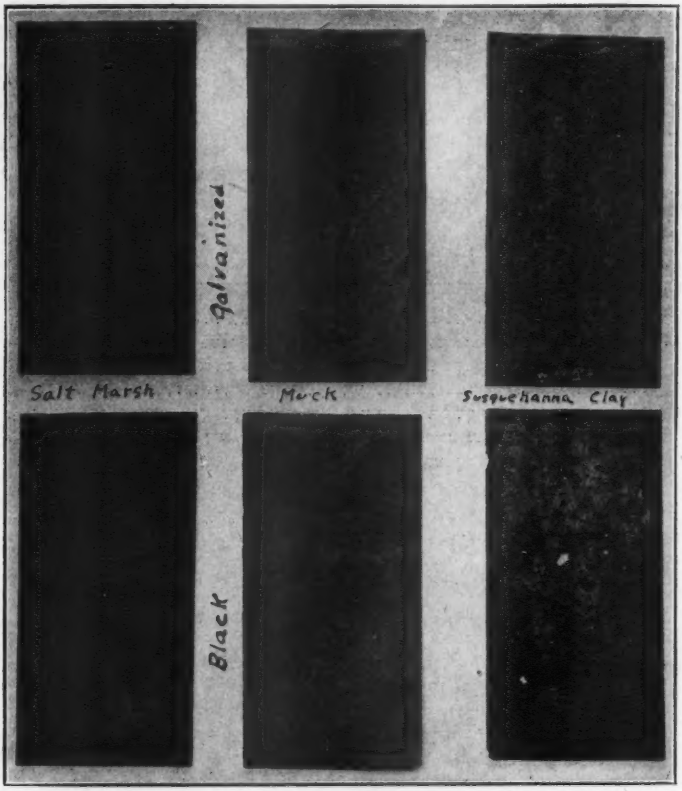

FIG. 6—GALVANIZED AND BLACK SHEET IN THREE SOILS

have been scrubbed in water with a fiber brush some of them appear as if varnished, and it seems probable that under certain soil conditions a film has been formed which offers substantial resistance to further corrosion. The appearance of the galvanized specimens in the strongly alkali soil indicates rapid deterioration of the coating in this soil.

In most of the locations under observation the soils which attack the steel specimens severely are also corrosive with respect

to galvanized material. There are, however, a few very marked exceptions to this statement. Fig. 5 shows specimens of steel, lead and galvanized iron from two soils about five miles apart. Fig. 6 shows black and galvanized sheet of the same gage buried in three soils, in one of which the galvanizing offered a very considerable protection, while in another, where the black iron corroded less than in the first soil, the galvanizing was almost completely removed.

The specimens so far removed do not indicate that the type of base material has any effect on the initial rate of corrosion. The importance of the kind of base metal and of the distribution of the zinc between pure zinc and alloy layers will be more evident after the experiment has continued longer. Later, specimens may also indicate the extent to which the remaining zinc retards corrosion after the base metal has been exposed in spots.

The lead specimens show little corrosion, except in a few soils where pitting of the lead is severe. The lead coated specimens, however, show serious pitting in many of the soils, as is illustrated in Fig. 7. This is probably due to pinholes in the coating.

The bituminous protective coatings were confined to such coatings as can be applied at a rolling mill or pipe yard and do not include coatings suitable for field application. The results of the tests are, in general, disappointing. The asphalt and tar dip coatings have deteriorated in a number of locations and their appearance suggests that they offer inadequate protection against severe soil conditions. The impregnated fabric coatings, especially the coal-tar-impregnated ones, are in better condition, but the asphalt-impregnated fabric has deteriorated in several locations and the pipe was slightly rusted. This shows that moisture penetrates the coating. The heavy tar dip coating on one class of specimens had too low a melting point and flowed after the specimens were buried, leaving parts of the pipe exposed. In several such cases the pitting of the partially protected pipe was worse than that of the unprotected material in the same trench, as is illustrated in Fig. 8.

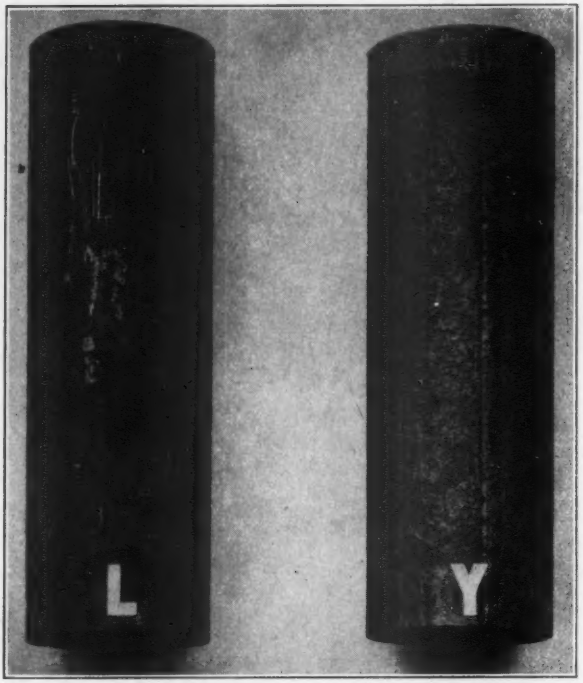

FIG. 7—LEAD COATED PIPE AND UNPROTECTED PIPE IN SALT MARSH—L, LEAD COATED PIPE, 2 YEARS; Y, UNCOATED PIPE, 4 YEARS

The tests are not comprehensive enough and tests of additional materials and methods of application seem very desirable.

3. *Types of Corrosion of Unprotected Iron and Steel.* In general, the 1926 unprotected specimens appear similar to those removed in 1924. While radically different materials are not affected similarly, there is a striking similarity in the appearance of the rolled materials in almost any of the soils under investigation. This is illustrated in Fig. 9, which shows specimens of pure open-hearth iron, wrought iron, bessemer steel, open-hearth steel and copper-bearing open-hearth steel, buried in Cecil clay

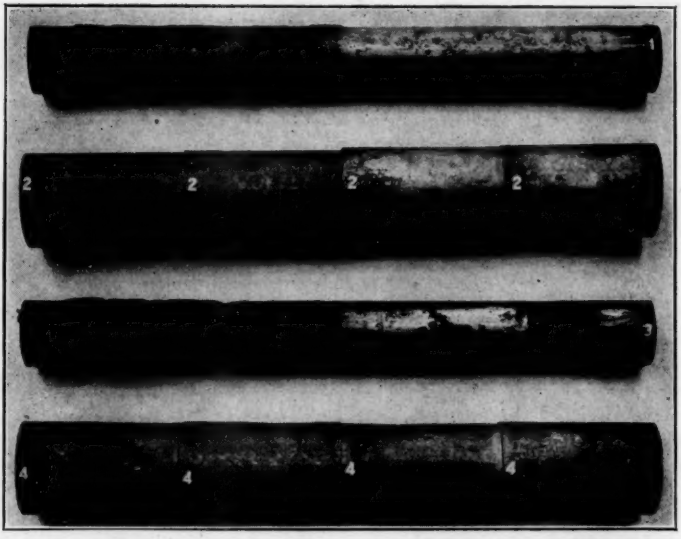

FIG. 8—ACCELERATED CORROSION DUE TO FAILURE OF COATING—(1) COATED PIPE AND (2) UNPROTECTED PIPE BURIED IN BLACK ALKALI IN HANFORD SOIL; (3) COATED PIPE AND (4) UNPROTECTED PIPE BURIED IN SALT MARSH

loam at Atlanta, Ga., for approximately four years. The similarity in the appearance of these specimens is duplicated in other localities and is an evidence of the controlling influence of the soil on the character of corrosion.

While all of the rolled specimens in a given soil show similar corrosion patterns, the types of corrosion vary widely in different soils as is illustrated in Fig. 10, which shows the corrosion patterns on bessemer steel in eight soils.

The specimens in Everett gravelly sandy loam, a well-drained soil, show almost no corrosion after four years. Those in the silt loam at Salt Lake City have lost their oxide coatings as if they had been pickled in dilute acid, but the surfaces are smooth and free from pits and the losses very small. The surfaces of the specimens in Keyport loam are roughened, but show

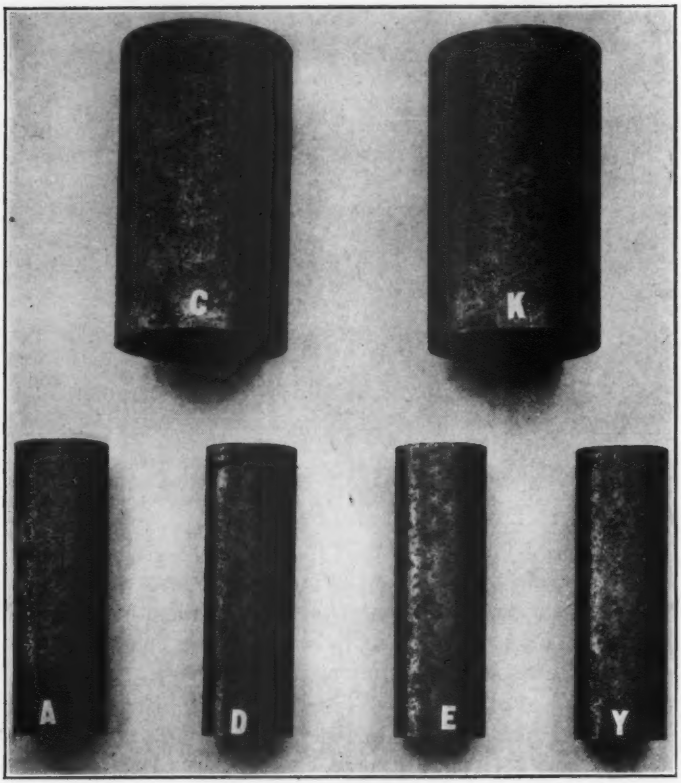

FIG. 9—SIX KINDS OF ROLLED PIPE FROM CECIL CLAY LOAM—NOTE SIMILARITY IN TYPES OF CORROSION

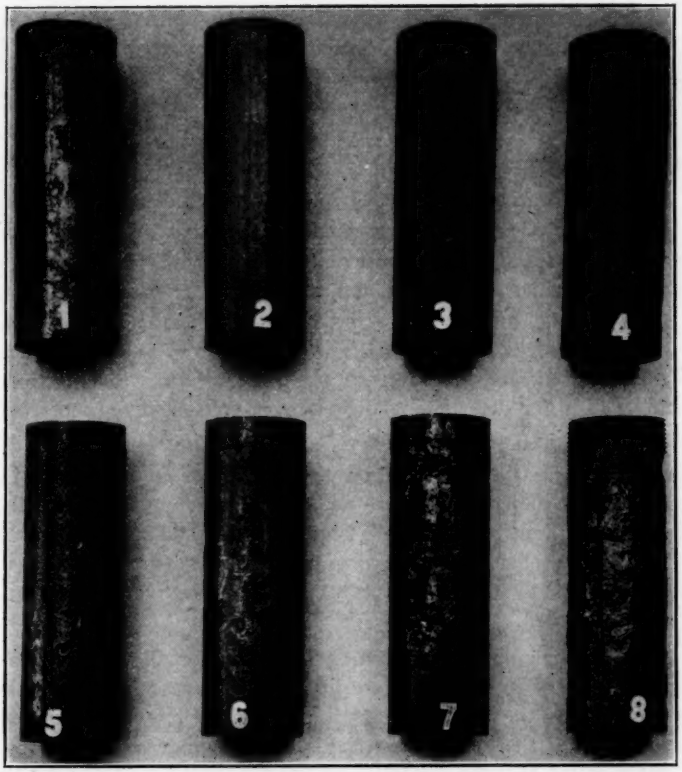

FIG. 10—TYPES OF CORROSION—(1) UNAFFECTED IN EVERETT GRAVELLY SAND LOAM; (2) ETCHED IN SILT LOAM; (3) ROUGHENED IN KEYPORT LOAM; (4) BLOTCHED IN MEMPHIS SILT LOAM; (5) FEW PITS IN HAGERSTOWN SANDY LOAM; (6) DEEP PITS IN MARSHALL SILT LOAM; (7) WORM EATEN IN SANDY LOAM; (8) CORRODED AREAS, HOLE IN WALL CORROSION AT WELD IN WHITE ALKALI

few distinct pits. Those in Memphis silt loam show patches of rather severe corrosion, although the original oxide coating remains on most of the surface. In Hagerstown sandy loam most of the original surface is intact, but there are few deep pits. Marshall silt loam specimens show numerous deep pits. Most of the specimens from the sandy loam in Denver show grooves as if they were worm eaten. Large patches of deep corrosion appear on the specimens in a white alkali soil in California and the thinner walled specimens have failed. In this soil there is especially severe corrosion along the butt welds.

These variations in types of corrosion indicate that some physical or chemical characteristic of the soil or the locality where the specimens are buried has a marked influence on the character of the corrosion and suggest that a thorough study of soils for the purpose of correlating their characteristics with corrosion might result in a knowledge of why some soils are corrosive, methods of overcoming or preventing their action, and means for determining their corrosiveness and the most desirable form of its mitigation.

Likewise the investigation to date indicates that while in many soils under observation the corrosion is not commercially important, in a few of them it is quite severe, and since comparatively few reliable data on protective coatings are available it seems that a comprehensive study of protective coatings is greatly needed.

Although the type of pitting is similar for all wrought materials in the same soil, there are, in some cases, considerable variations in the corrosion losses and depth of pits. The present indication is that no one material is superior under all conditions, but it is felt that this tentative conclusion may have to be modified in the light of later data.

4. *Summary of Corrosion Data.* Tables have been prepared showing the rates of corrosion and pitting and the pitting factor for each bare pipe specimen removed in 1926. Because of the number of specimens involved and the variations between specimens nominally the same, these tables are difficult to inter-

Table 1

COMPARISON OF RATES OF CORROSION IN OUNCES PER SQUARE FOOT PER YEAR AT END OF FIRST AND SECOND PERIOD.

No.	Soil	Times of Burial, Years		Wrought Iron (4)		Bessemer Steel (6)		Pure Open Hearth Iron		Open Hearth Steel		Copper Bearing Open Hearth Steel		Sand Mould Cast Iron		De Lavaud Cast Iron	
		Period		Period		Period		Period		Period		Period		Period		Period	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
1	Alkali soil	1.18	3.78	1.07	0.78	1.24	0.79	1.02	0.96	0.83	0.85	1.18	0.86	1.38	1.11	1.15	2.06
2	Alkali in Montezuma adobe	1.64	Late	1.76	Late	1.92	Late	2.04	Late	1.94	Late	2.15	Late	2.86	Late	2.76	Late
3	Allis loam	0.98	3.58	1.16	1.16	1.19	1.12	1.09	0.92	1.39	1.17	1.17	0.96	1.43	1.05	0.80	0.96
4	Bell clay	2.09, 1.94*	4.03	0.94	0.80	1.03	0.75	0.90	0.71	1.05	0.68	0.88	0.62	0.92	0.97	0.43	Late
5	Black alkali in Hanford loam	1.93	4.22	1.76	1.18	2.12	0.92	1.28	0.64	2.33	0.55	2.11	1.11	1.90	1.99	1.41	0.68
6	Cecil clay loam	2.01, 2.07*	4.09	0.85	0.83	0.97	0.84	0.73	0.70	0.98	0.81	0.86	0.89	0.98	1.03	0.58	Late
7	Chester loam	1.38	4.03	0.86	0.90	1.04	0.87	1.06	0.91	1.01	0.91	1.12	0.92	0.98	1.01	0.90	0.90
8	Clay	1.96, 2.10*	4.06	1.12	1.04	1.06	1.00	1.09	0.97	1.28	1.05	1.45	1.02	1.16	1.42	1.12	Late
9	Dublin clay loam	1.93, 2.20*	4.13	0.49	0.53	0.61	0.57	0.57	0.35	0.51	0.51	0.49	0.50	0.46	0.42	1.17	Late
10	Everett gravelly sandy loam	1.93	4.13	0.07	0.15	0.09	0.18	0.07	0.17	0.07	0.17	0.08	0.13	0.06	0.08	0.12	Late
11	Fairmount loam	1.04	3.50	0.62	0.73	0.61	0.70	0.46	0.70	0.51	0.83	0.59	0.72	1.25	0.84	0.60	0.76
12	Fargo clay loam	1.13	3.80	0.59	0.47	0.68	0.51	0.64	0.50	0.54	0.45	0.64	0.48	1.24	1.06	0.69	0.49
13	Genesee silt loam	1.03	3.48	0.86	0.65	0.73	0.59	0.54	0.49	0.61	0.35	0.52	0.49	0.69	0.66	0.70	0.41
14	Gloucester sandy loam	1.33	4.01	0.89	0.45	0.98	0.49	1.01	0.34	0.78	0.30	0.88	0.39	0.71	0.54	0.75	0.43
15	Hagerstown sandy loam	1.36	3.97	0.30	0.26	0.33	0.27	0.20	0.23	0.29	0.23	0.26	0.24	0.17	0.22	0.07	0.16
16	Hanford fine sandy loam	1.94, 2.21*	4.14	0.11	0.41	0.17	0.39	0.13	0.34	0.12	0.37	0.13	0.39	0.12	0.38	0.03	Late
17	Hempstead silt loam	1.13	3.80	0.32	0.62	0.42	0.63	0.23	0.52	0.41	0.59	0.40	0.51	0.26	0.60	0.24	0.30
18	Houston black clay	1.96, 2.08*	4.04	1.10	0.75	1.21	0.83	1.25	0.89	1.15	0.83	1.38	0.76	0.97	0.83	1.15	Late
19	Keyport loam	1.21	3.83	1.27	0.90	1.23	0.90	1.22	0.86	1.24	0.90	1.20	0.95	1.92	0.96	1.14	0.94
20	Knox silt loam	1.19	3.74	0.47	0.42	0.42	0.42	0.35	0.32	0.27	0.30	0.40	0.44	(‡)	0.27	0.21	0.16
21	Lindley clay loam	1.12	3.66	0.65	0.51	0.63	0.57	0.56	0.54	0.56	0.62	0.75	0.55	0.49	0.35	0.34	0.37
22	Mahoning silt loam	0.98	3.57	0.90	0.64	1.05	0.58	0.95	0.60	1.05	0.60	0.95	0.56	1.11	0.67	0.75	0.51
23	Marshall silt loam	1.47	4.02	1.45	0.67	1.43	0.68	1.37	0.63	1.35	0.73	1.44	0.62	1.53	0.79	1.09	0.62
24	Memphis silt loam	1.72	3.68	0.84	1.01	1.13	0.96	0.80	0.87	0.85	1.00	0.99	0.94	0.85	1.11	0.59	0.67
25	Merrimac gravelly sandy loam	1.32	4.01	0.17	0.12	0.21	0.11	0.15	0.11	0.20	0.09	0.15	0.08	0.11	0.09	0.13	0.05
26	Miami clay loam	1.03	3.71	0.45	0.28	0.42	0.28	0.43	0.19	0.36	0.23	0.40	0.28	0.48	0.45	0.47	0.30

*Time of burial of De Lavaud cast iron. It was buried in these locations when first specimens were removed.
†These specimens are included with extra specimens.
‡Specimens damaged before weighing.

(Concluded on next page)

Table 1

(Concluded)

COMPARISON OF RATES OF CORROSION IN OUNCES PER SQUARE FOOT PER YEAR AT END OF FIRST AND SECOND PERIODS

No.	Soil	Times of Burial, Years		Wrought Iron (4)		Bessemer Steel (6)		Pure Open Hearth Iron		Open Hearth Steel		Copper Bearing Open Hearth Steel		Sand Mould Cast Iron		De Lavaud Cast Iron	
		Period		Period		Period		Period		Period		Period		Period		Period	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
27	Miami silt loam	1.04	3.49	0.84	0.60	0.81	0.56	0.76	0.45	0.73	0.55	0.87	0.54	1.04	0.95	0.76	0.56
28	Muck	1.96	4.07	1.74	1.84	2.10	1.73	2.04	1.78	2.17	1.79	2.14	1.94	1.98	2.51	(†)	Late
29	Muscatine silt loam	1.11	3.65	0.81	0.36	0.94	0.35	0.81	0.30	0.96	0.35	0.91	0.34	1.12	0.51	1.04	0.45
30	Norfolk fine sandy loam	1.97, 2.07*	4.04	1.17	0.83	1.26	0.81	0.96	0.71	1.13	0.74	1.06	0.85	1.24	0.59	0.76	Late
31	Norfolk sand	2.01, 2.07*	4.07	0.52	0.46	0.68	0.53	0.34	0.50	0.62	0.62	0.53	0.56	0.37	0.45	1.09	Late
32	Ontario loam	0.94	3.73	0.42	0.42	0.40	0.39	0.27	0.31	0.41	0.35	0.34	0.38	0.40	0.53	0.51	0.42
33	Peat	1.03	3.71	0.39	0.95	0.42	0.94	0.42	0.94	0.44	0.93	0.35	1.02	0.35	0.88	0.42	0.92
34	Penn silt loam	1.38	4.03	0.96	0.45	0.89	0.45	0.95	0.40	0.98	0.46	0.85	0.44	0.94	0.45	0.90	0.43
35	Ramona loam	1.93, 2.20*	4.14	0.43	0.50	0.44	0.41	0.42	0.41	0.47	0.47	0.48	0.43	0.60	0.70	0.51	Late
36	Ruston fine sandy loam	1.99, 2.08*	4.07	0.52	0.45	0.58	0.49	0.58	0.35	0.42	0.42	0.47	0.37	0.47	0.32	0.36	Late
37	St. John sand	2.00, 2.07*	4.07	1.17	1.09	1.21	1.08	1.15	1.03	1.20	1.09	1.13	1.21	0.83	1.00	1.95	Late
38	Salt marsh	1.29	4.06	1.45	1.48	1.82	1.34	1.05	0.90	1.70	1.28	1.85	1.58	0.90	0.93	0.77	0.77
39	Sandy loam	1.46	4.05	0.79	0.69	0.76	0.67	0.53	0.68	0.76	0.63	0.81	0.79	0.46	1.17	0.34	0.55
40	Sassafras gravelly sandy loam	1.40	4.04	0.13	0.15	0.19	0.15	0.11	0.11	0.18	0.10	0.20	0.13	0.06	0.09	0.03	0.07
41	Sassafras silt loam	1.38	4.02	0.85	0.80	0.87	0.74	0.75	0.78	0.99	0.76	0.90	0.73	1.02	0.74	0.86	0.71
42	Silt loam	1.48	4.08	0.27	0.39	0.30	0.41	0.35	0.31	0.39	0.32	0.25	0.50	0.38	0.59	0.40	0.46
43	Summit silt loam	1.47	4.02	0.40	0.77	0.44	0.70	0.51	0.68	0.43	0.73	0.27	0.62	0.82	0.65	0.26	0.46
44	Susquehanna clay	1.98	4.07	1.64	1.49	1.57	1.36	1.51	1.09	1.20	0.83	0.97	0.84	2.45	2.28	(†)	Late
45	Swampland	1.95, 2.11*	4.05	0.31	0.82	0.27	0.89	0.20	0.80	0.29	0.86	0.24	0.66	0.24	0.73	1.10	Late
46	Wabash silt loam	1.09	3.63	0.47	0.45	0.38	0.47	0.30	0.38	0.32	0.38	0.38	0.35	0.58	0.32	0.15	0.27
47	White alkali soil	1.93	4.27	3.48	2.95	3.85	2.82	2.80	2.62	3.38	2.79	4.06	2.26	7.11	6.74	2.96	2.89

*Time of burial of De Lavaud cast iron. It was buried in these locations when first specimens were removed.
†These specimens are included with extra specimens.

pret, and, for most purposes, the summary of the results[3] as given in Tables 1 and 2 is of greater interest. In these tables, similar materials have been grouped together. The number of specimens in the group ranges between two and six. Not all the specimens in the larger groups are from the same manufacturer or are made in exactly the same way, but examination of the detailed data will show that the variations between the specimens of different materials grouped together is of the same order of magnitude as that between specimens of the same material. The tables are intended to bring out the progress of the investigation and for this reason show both 1924 and 1926 data. For reasons discussed elsewhere the data should not be used for determining the relative merits of materials.

Table 1 shows the rates of corrosion as indicated by the losses in weight. The cast iron specimens have been weighed to 0.1 gram (0.0035 oz.). The 1½-inch and 3-inch specimens have been weighed to 0.02 gram (0.00076 oz.). The differences in the losses of two specimens of the same material in the same soil is frequently greater than the largest of the above figures. The reason for this has already been discussed.

The specimens buried in 1922 were exposed to the soil on both surfaces. For the wrought specimens this is proper since the two surfaces are similar. This is not strictly true for the De Lavaud cast iron, and for this reason the specimens of this material buried in 1924 had the inner surfaces protected. This change should be kept in mind when comparing data involving these specimens.

Table 1 shows the rates of corrosion for each kind of material tested at the first and second examination (1924 and 1926). Since the irregularities in all soils and different materials were not the same, a basis for computing the probable error in the data is lacking. If we assume 0.05 ounce per square foot to be the smallest figure which is significant, we find that out of 306 cases in which we may compare the losses at the end of the two

[3] Credit is due to the author's associates, S. Ewing, C. D. Yeomans and E. J. Michael for the measurements and computations required for the preparation of these tables.

periods, in 170, or 56 per cent, there is a decrease in the rate of corrosion, while 74, or 25 per cent, there is an increase in the rate.

From the standpoint of soils, we find that in 25 soils four or more materials showed a decreased rate of corrosion with not more than one material showing accelerated corrosion, while in 10 soils four or more materials showed accelerated corrosion with not more than one material showing a decreased rate. The cast iron deviates from the general trend of the specimens more often than any other material.

Table 2 shows the data on rates of pitting for each material in each soil under investigation. When these data were collected it did not seem desirable to measure pits less than 0.02 inch in depth. This results in a large number of blank spaces in Table 2 and makes comparisons of soils or materials difficult. Only one case is shown where there is an increased rate of corrosion, although more might appear if we had the data on the rates of pitting which the table does not show. Nevertheless, it seems reasonably safe to conclude that in most cases there is a decreased rate of corrosion, and that in many instances the decrease in rate of pitting is greater than in the rate of corrosion. This would mean that corrosion not only tends to decrease, but that the corrosion products tend to retard the corrosion beneath them.

The data on the cast materials furnished through the American Foundrymen's Association and buried in 1924 are summarized in Table 3.

The specimens of fiber pipe have not been included in these tables because they must be judged by different methods. Many of these specimens absorbed some water and elongated. Whether this was due to failure of the protective coating or to injuries to the coating in many cases cannot be determined.

In a few places there are evidences of deterioration of the coating. On some specimens the coating is blistered, while on others it shows cracks. The fiber, in some locations, appears to

Table 2

COMPARISON OF RATES OF PENETRATION IN THOUSANDTHS OF INCHES PER YEAR AT END OF FIRST AND SECOND PERIODS

No.	Soil	Times of Burial, Years		Wrought Iron (4)		Bessemer Steel (6)		Pure Open Hearth Iron		Open Hearth Steel		Copper Bearing Open Hearth Steel		Sand Mould Cast Iron		De Lavaud Cast Iron	
		Period		Period		Period		Period		Period		Period		Period		Period	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
1	Alkali soil	1.18	3.78	..	8	19	7	..	9	14	9	23	12	38	14	..	12
2	Alkali in Montezuma adobe	1.64	...	16	Late	19	Late	12	Late	24	Late	22	Late	31	Late	19	Late
3	Allis loam	0.98	3.58	..	10	..	11	..	13	..	10	..	13	45	29	..	17
4	Bell clay	2.09	4.03	..	11	..	11	..	13	..	11	..	11	19	10	..	Late
5	Black alkali in Hanford loam	1.93	4.22	20	11	25	11	18	6	33	13	37	15	..	35	16	13
6	Cecil clay loam	2.01	4.09	25	16	25	18	31	18	26	13	30	22	32	16	..	Late
7	Chester loam	1.38	4.03	..	6	..	7	..	8	..	8	..	10	24	12	..	8
8	Clay	1.96, 2.10*	4.06	15	11	17	10	23	15	20	11	22	11	16	13	18	Late
9	Dublin clay loam	1.93, 2.20*	4.13	..	7	..	8	..	7	..	7	..	8	..	9	19	Late
10	Everett gravelly sandy loam	1.93	4.13	..	..	..	..	..	..	..	..	..	..	..	..	..	Late
11	Fairmount loam	1.04	3.50	..	..	..	..	..	8	..	9	..	..	..	..	..	..
12	Fargo clay loam	1.13	3.80	30	10	34	11	38	12	38	13	54	15	59	18	..	15
13	Genesee silt loam	1.03	3.48	38	15	24	17	44	13	31	17	32	18	..	10	..	..
14	Gloucester sandy loam	1.33	4.01	16	6	14	3	19	3	15	3	19	5	..	..	..	..
15	Hagerstown sandy loam	1.36	3.97	27	17	24	16	36	16	24	13	31	15	..	9	26	6
16	Hanford fine sandy loam	1.94	4.14	..	10	..	11	..	10	..	9	..	13	..	11	..	Late
17	Hempstead silt loam	1.13	3.80	31	16	28	14	29	14	28	15	57	19	24	..	..	..
18	Houston black clay	1.96, 2.08*	4.04	19	7	20	9	15	11	17	8	22	12	40	12	14	Late
19	Keyport loam	1.21	3.83	..	6	..	6	..	5	..	6	..	..	39	6	..	..
20	Knox silt loam	1.19	3.74	18	10	14	11	22	10	24	14	23	9	..	25	..	10
21	Lindley clay loam	1.12	3.66	23	11	24	13	30	10	22	12	34	13	..	21	..	9
22	Mahoning silt loam	0.98	3.57	..	..	..	..	..	..	..	..	..	..	..	..	..	..
23	Marshall silt loam	1.47	4.02	..	12	..	13	..	15	..	9	..	11	..	15	..	10
24	Memphis silt loam	1.72	3.68	21	14	27	14	25	12	22	16	27	14	32	25	18	13
25	Merrimac gravelly sandy loam	1.32	4.01	..	..	..	..	..	..	..	..	..	..	..	..	..	..
26	Miami clay loam	1.03	3.71	20	8	23	10	23	9	26	8	24	9	..	10	..	10

*Time of burial of De Lavaud cast iron pipes.
Blanks indicate pits were less than 0.02 inch total depth.

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Table 2

(Concluded)

COMPARISON OF RATES OF PENETRATION IN THOUSANDTHS OF INCHES PER YEAR AT END OF FIRST AND SECOND PERIODS

No.	Soil	Times of Burial, Years		Wrought Iron (4)		Bessemer Steel (6)		Pure Open Hearth Iron		Open Hearth Steel		Copper Bearing Open Hearth Steel		Sand Mould Cast Iron		De Lavaud Cast Iron	
		Period		Period		Period		Period		Period		Period		Period		Period	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
27	Miami silt loam	1.04	3.49	..	11	..	14	..	11	..	13	..	14	..	11	..	9
28	Muck	1.96	4.07	20	14	26	15	24	16	35	19	19	22	21	12	(†)	Late
29	Muscatine silt loam	1.11	3.65	..	5	13	3	21	4	15	4	16	5	..	..	..	..
30	Norfolk fine sandy loam	1.97, 2.07*	4.04	19	12	20	14	21	11	17	11	22	17	23	14	15	Late
31	Norfolk sand	2.01, 2.07*	4.07	17	9	26	7	15	..	23	11	27	8	..	9	20	Late
32	Ontario loam	0.94	3.73	29	11	25	8	43	12	24	9	29	11	36	10	..	12
33	Peat	1.03	3.71	..	..	..	9	..	10	..	8	..	10	..	11	..	12
34	Penn silt loam	1.38	4.03	16	5	15	4	14	6	20	4	21	6	..	7	..	7
35	Ramona loam	1.93	4.14	..	..	..	..	..	..	..	..	..	..	..	8	..	Late
36	Ruston fine sandy loam	1.99, 2.08*	4.07	19	9	19	9	14	9	24	12	19	10	24	12	15	Late
37	St. John sand	2.00	4.07	19	12	25	15	18	11	21	14	45	23	..	..	..	Late
38	Salt marsh	1.29	4.06	31	18	30	13	14	9	35	19	29	14	..	24	..	14
39	Sandy loam	1.46	4.05	35	16	38	22	39	20	26	14	54	27	24	13	..	..
40	Sassafras gravelly sandy loam	1.40	4.04	..	..	..	..	..	..	..	..	..	..	..	..	..	..
41	Sassafras silt loam	1.38	4.02	..	..	..	8	..	10	..	6	..	11	..	9	..	8
42	Silt loam	1.48	4.08	..	..	..	..	..	..	..	..	..	..	..	..	..	..
43	Summit silt loam	1.47	4.02	28	10	26	11	13	8	21	9	21	9	18	10	..	..
44	Susquehanna clay	1.98	4.07	28	19	31	19	27	15	31	20	28	18	50	38	(†)	Late
45	Swampland	1.95, 2.11*	4.05	..	9	..	9	..	..	..	9	..	10	..	15	13	Late
46	Wabash silt loam	1.09	3.63	29	12	28	14	34	21	36	12	35	14	..	19	..	12
47	White alkali soil	1.93	4.27	25	23	26	24	28	21	45	31	34	22	60	60	18	33

*Time of burial of De Lavaud cast iron pipes.
†These specimens are included with extra specimens.
Blanks indicate pits were less thant 0.02 inch total depth.

Table 3

SUMMARY OF DATA ON A. F. A. SPECIMENS

Soil		A	I	CC	MC	M	S	E	V
Casper (Alkali Soil)	Loss in ounces per square foot per year....	1.67	....	0.85	0.45	1.12	0.36	0.43	0.63
	Maximum penetration, mils per year.....	12	....	....	....	....	....	12	....
	Time buried 2.60 years.								
San Diego (Alkali in Montezuma Adobe)	Loss in ounces per square foot per year....	N. S.	....	N. S.	N. S.	N. S.	2.21	2.49	N. S.
	Maximum penetration, mils per year.....	N. S.	....	N. S.	N. S.	N. S.	20	28	N. S.
	Time buried 1.6 years.								
Bakersfield (Black Alkali in Hanford Loam)	Loss in ounces per square foot per year....	0.49	....	0.29	1.60	1.47	1.10	1.21	1.30
	Maximum penetration, mils per year.....	....	....	....	22	33	....	37	....
	Time buried 2.29 years.								
Norwood (Merrimac Gravelly Sandy Loam)	Loss in ounces per square foot per year....	0.16	....	0.15	0.18	0.23	0.36	0.35	0.20
	Maximum penetration, mils per year.....	....	....	....	....	24	....	....	....
	Time buried 2.69 years.								
New Orleans (Muck)	Loss in ounces per square foot per year....	2.45	....	3.24	1.99	1.89	2.30	2.07	1.68
	Maximum penetration, mils per year.....	20	....	17	20	34	17	18	21
	Time buried 2.11 years.								
Elizabeth (Salt Marsh)	Loss in ounces per square foot per year....	0.78	....	1.27	1.17	1.44	1.22	0.92	1.00
	Maximum penetration, mils per year.....	31	....	63	10	10	17	23	9
	Time buried 2.78 years.								
Meridian (Susquehanna Clay)	Loss in ounces per square foot per year....	1.82	....	1.14	1.68	N. S.	1.99	1.41	1.84
	Maximum penetration, mils per year.....	31	27	23	30	N. S.	29	36	32
	Time buried 2.08 years.								

Materials indicated by column headings:

A 6-inch Southern cast iron.
I 6-inch sand cast centrifugal.
CC 6-inch De Lavaud cast iron.
MC 6-inch machined cast iron (De Lavaud).
M 4-inch machined cast iron.
V 2-inch high tensile cast iron.
S 45° malleable cast iron ells.
E 90° cast steel elbows.
N.S. No specimens.

be somewhat softened, but the extent to which the specimens have weakened has not been determined.

The tables also omit the high-silicon cast iron. This material, in all locations, showed very little corrosion. In a few places it was darkened and showed rusted areas, but in no location was there a commercially important loss of weight or pitting.

IV. *Correlation of Corrosion and Soil Characteristics*

The data presented above indicate quite definitely that the corrosion of buried metallic structures is largely influenced by the physical or chemical characteristics of the soil or, at least, by some phenomena associated with the location of the structure. It is natural to expect that the solution of sub-surface corrosion problems will be effected, at least in part, through an understanding of soil characteristics. An attempt has been made, therefore, to associate some of the soil characteristics with the corrosion observed.

Table 4 gives the hydrogen ion concentrations and water soluble salts of most of the soils under investigation. The 1926 hydrogen ion values were taken in the field with a colorometric apparatus and are not considered entirely reliable, because of lack of a standard method of making such determinations, the possible fading of the reference colors, the few tests made and the presence of small amounts of carbon dioxide in the distilled water used. In a few soils, exact color matches were impossible.

The reader's attention is called especially to the wide variations in both the hydrogen ion concentrations and water soluble salts in a number of the soils. Since these quantities will be affected by the season of the year, in many locations, and since it is not known whether corrosion progresses at a uniform rate or only at certain periods, it is evident that a close association of the observed corrosion and the data of Table 5 cannot be expected. Nevertheless, such an association is of interest and some of the data in Tables 1, 2 and 4 have been plotted in Figs. 11, 12, 13 and 14.

Table 4

HYDROGEN ION CONCENTRATION AND WATER SOLUBLE SALTS IN SOILS

Soil No.*	Bureau of Soils Hydrogen Ion Values			1926, Field Determinations	1922, Percentage of Soluble Salts		
	Maximum	Minimum	Average		Maximum	Minimum	Average
1	...	...	...	7.9	....	....	....
2	...	...	...	...	....	....	....
3	...	...	...	6.1	....	....	....
4	7.5	5.7	6.6	7.0	0.067	0.025	0.046
5	10.2	8.2	9.1	7.3	0.342	0.038	0.221
6	4.9	4.6	4.8	5.7	0.014	0.009	0.011
7	7.4	7.0	7.2	5.5	0.032	0.018	0.025
8	6.1	5.1	5.7	5.3	0.020	0.016	0.018
9	8.4	5.2	6.5	...	0.180	0.021	0.077
10	5.8	5.6	5.7	6.4	0.012	0.007	0.010
11	...	...	...	6.5	....	....	....
13	...	...	...	7.1	....	....	....
12	...	...	...	7.4	....	....	....
14	5.1	4.8	5.0	5.2	0.027	0.009	0.017
15	5.8	5.8	5.8	6.2	0.014	0.010	0.012
16	8.5	5.8	7.2	6.9	0.085	0.017	0.035
17	6.0	5.5	5.7	6.7	0.055	0.034	0.041
18	8.2	7.6	7.9	7.0	0.154	0.064	0.099
19	4.3	3.4	3.8	5.7	0.016	0.016	0.016
20	7.9	7.3	7.5	7.1	0.089	0.047	0.057
21	5.4	4.6	5.0	6.7	0.010	0.008	0.009
22	...	...	...	6.7	....	....	....
23	7.8	5.4	6.2	6.8	0.056	0.013	0.028
24	...	...	...	6.2	....	....	....
25	5.3	4.6	5.1	5.6	0.015	0.007	0.010
26	7.9	7.1	7.4	7.3	0.036	0.022	0.031
27	...	...	...	7.2	....	....	....
28	5.5	3.5	4.5	5.3	0.166	0.063	0.101
29	...	...	...	7.2	....	....	....
30	5.1	3.9	4.5	5.6	0.008	0.007	0.007
31	6.8	5.8	6.3	6.2	0.016	0.011	0.013
32	...	...	...	6.9	....	....	....
33	7.8	7.8	7.8	7.2	0.192	0.192	0.192
34	4.6	4.5	4.5	6.9	0.032	0.012	0.022
35	7.4	7.2	7.3	7.2	0.064	0.053	0.059
36	6.1	4.9	5.4	6.0	0.008	0.007	0.008
37	5.5	4.6	5.1	5.7	0.024	0.007	0.013
38	...	...	...	7.4	....	....	....
39	8.1	6.5	7.4	7.2	0.088	0.051	0.069
40	4.8	4.4	4.6	5.7	0.008	0.007	0.007
41	6.4	5.4	5.9	6.6	0.014	0.011	0.013
42	8.2	8.0	8.1	7.0	0.197	0.088	0.127
43	7.6	5.2	6.4	6.8	0.042	0.020	0.031
44	4.6	4.1	4.4	5.8	0.007	0.007	0.007
45	...	...	...	7.3	....	....	....
46	8.3	5.5	6.6	7.0	0.048	0.016	0.030
47	9.2	8.2	8.9	7.5	2.100	1.316	1.574

*See Table 1 for soil names.

Table 5

SOIL DATA

Soil No.*	Resistivity, Ohm—cm. 1922	1923	1926	Water Table†
1	2,600	251	310	V
2	.....	.....	528	B
3	5,180	3,350	.....	B
4	.....	.....	892	B
5	6,020	.....	8,640	B
6	57,000	.....	85,300	B
7	10,700	.....	14,600	B
8	.....	.....	3,880	V
9	1,060	.....	626	V
10	534,000	.....	502,000	B
11	.....	1,410	1,890	B
12	316	488	412	B
13	3,300	2,690	2,500	V
14	99,000	.....	84,600	B
15	44,500	.....	22,900	B
16	20,200	.....	5,500	B
17	.....	24,200	33,000	B
18	306	.....	337	B
19	.....	.....	13,600	V
20	.....	1,990	2,400	B
21	1,830	2,400	1,840	B
22	3,880	3,610	4,800	B
23	1,840	2,780	2,890	B
24	.....	.....	7,000	B
25	.....	500,000	792,000	B
26	12,600	3,320	4,690	B
27	16,500	6,880	5,040	B
28	1,900	.....	1,670	A
29	860	.....	1,210	B
30	20,900	.....	40,300	V
31	.....	.....	119,000	B
32	10,000	8,000	6,000	B
33	1,570	.....	.....	V
34	4,970	.....	4,140	B
35	2,000	.....	.....	B
36	.....	.....	129,000	B
37	.....	.....	27,200	V
38	62	.....	64	A
39	.....	5,610	4,080	B
40	266,000	.....	84,300	B
41	12,500	.....	4,500	B
42	1,400	1,510	1,000	A
43	2,400	3,650	2,100	B
44	.....	.....	24,300	B
45	.....	.....	630	A
46	1,560	1,340	.....	B
47	390	.....	370	B

*For soil names, see Table 1.

†A—Usually above specimens; B—Permanently below specimens; V—Variable (above and below).

It is apparent that while there is, in general, an increase in corrosion as soils become more acid or alkaline, this alone does not offer a key to the corrosion problem. It has been suggested that if similar curves were plotted for soils of the same texture the results might be more favorable. Unfortunately, sufficient data for such curves are not available.

Figs. 13 and 14 indicate that corrosion is often more rapid in soils high in soluble salts, but that the salt content is not always the controlling factor.

A further study of the relation of soil waters to corrosion was made with the cooperation of W. D. Collins, of the U. S. Geological Survey, who analyzed waters taken from four soils in which specimens were buried and plotted graphs showing the proportionate parts of the salts found. These we have paralleled with graphs showing rates of pitting and corrosion. The result is given in Fig. 15. Total immersion corrosion tests of pure open hearth iron in these waters were made by J. R. Cain, of the American Rolling Mill Co., who found substantially the same losses in each of the four waters.

Table 5 gives field values of the soil resistivity. This also varies from point to point in the same trench and from season to season. Fig. 16 is an attempt to relate corrosion with soil resistivity.

Evidently there are several, and probably there are many, factors affecting subsoil corrosion.

V. *Laboratory Investigation*

1. *Examination of Soil Samples.* The field study of soil corrosion was intended to be of a practical nature, with results directly applicable to the conditions encountered by pipe users. For this reason commercial pipe was used for specimens, and the pipes were buried much as they would be under service conditions. On this account there were variations, both in pipes and soils, nominally identical, and complex conditions were introduced which could only be analyzed with great difficulty, if at all. The heats from which the metals were poured are unknown, and

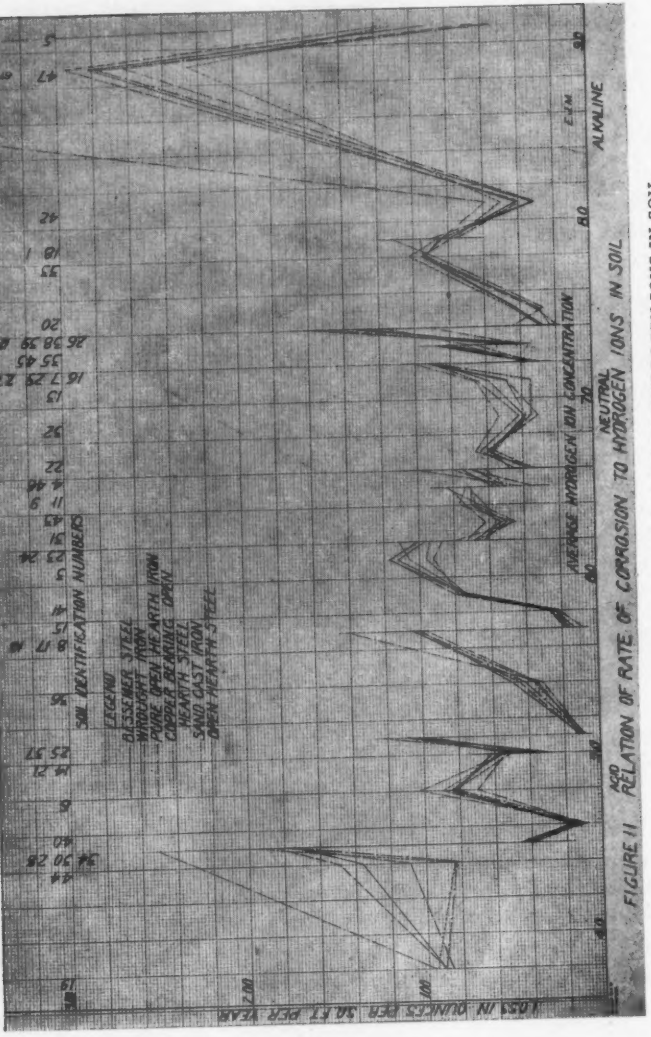

FIGURE 11 RELATION OF RATE OF CORROSION TO HYDROGEN IONS IN SOIL

FIG. 11—RELATION OF RATE OF CORROSION TO HYDROGEN IONS IN SOIL

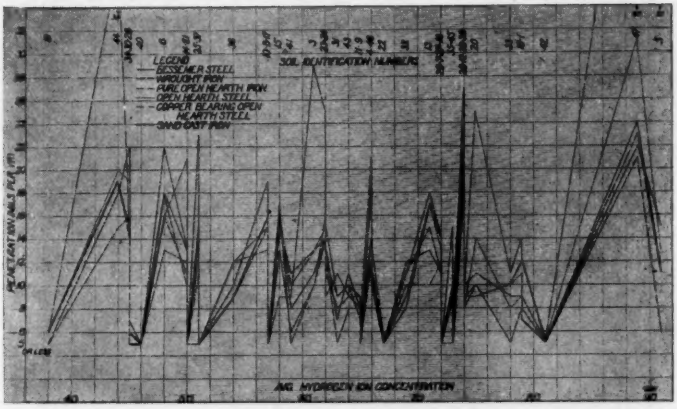

FIG. 12—RELATION OF RATE OF PITTING TO HYDROGEN IONS IN SOIL

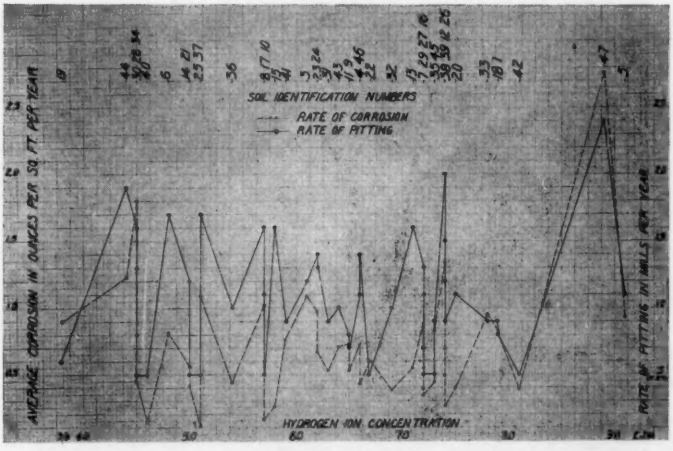
SOIL IDENTIFICATION NUMBERS
RATE OF CORROSION
RATE OF PITTING
AVERAGE CORROSION IN OUNCES PER SQ. FT. PER YEAR
RATE OF PITTING IN MILLS PER YEAR
HYDROGEN ION CONCENTRATION

FIG. 13—RELATION OF AVERAGE CORROSION RATE TO HYDROGEN ION CONCENTRATION

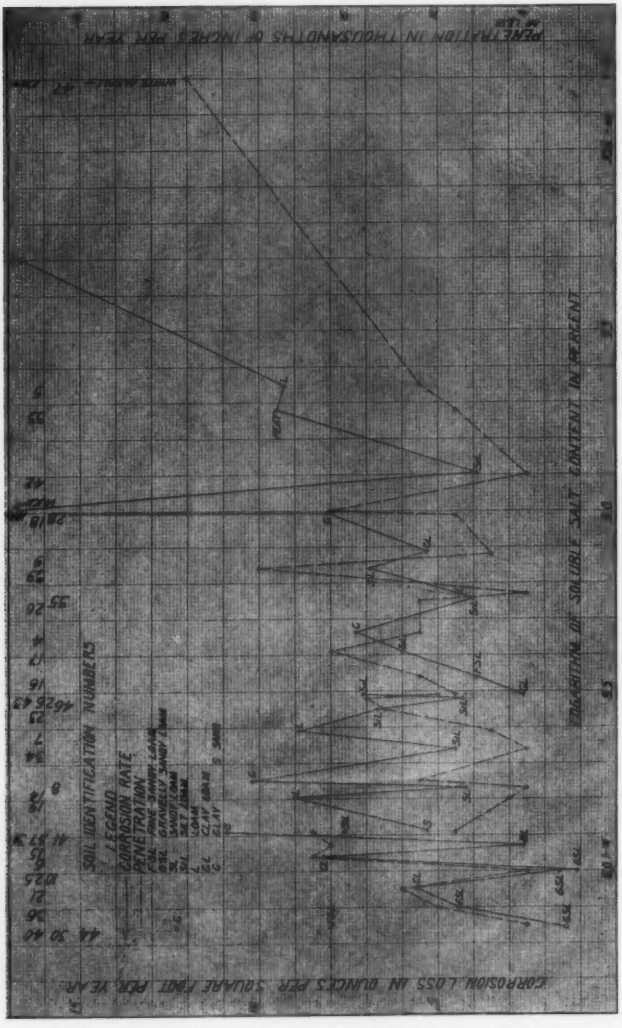
CORROSION LOSS IN OUNCES PER SQUARE FOOT PER YEAR
PENETRATION IN THOUSANDTHS OF INCHES PER YEAR
SOIL IDENTIFICATION NUMBERS
LEGEND
CORROSION RATE
PENETRATION
INCREASE OF SOLUBLE SALT CONTENT IN PERCENT

FIG. 14—RELATION OF RATES OF CORROSION AND PITTING TO SOLUBLE SALTS

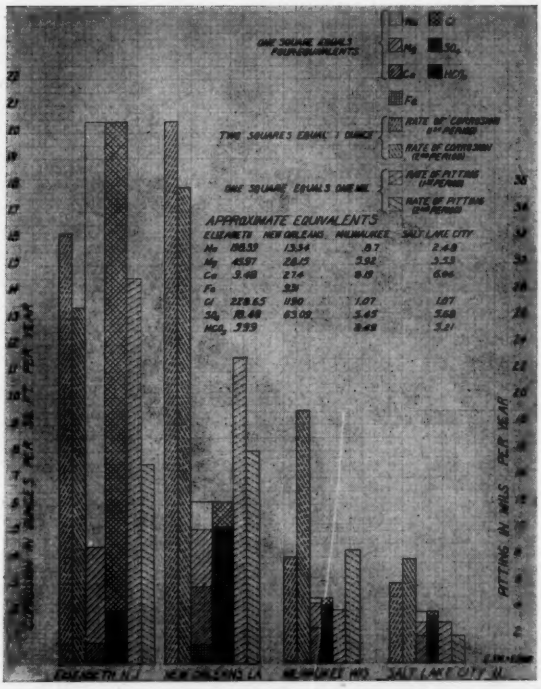
ONE SQUARE EQUALS FOUR EQUIVALENTS
TWO SQUARES EQUAL 1 OUNCE
ONE SQUARE EQUALS ONE MIL
APPROXIMATE EQUIVALENTS
ELEMENTS NEW ORLEANS MILWAUKEE SALT LAKE CITY
Na 188.39 13.54 .87 2.48
Mg 45.97 28.15 3.92 3.53
Ca 9.48 27.4 8.19 6.96
Fe 9.31
Cl 278.65 11.90 1.07 1.07
SO4 18.48 63.09 5.45 5.68
HCO3 5.93 8.48 3.21
PITTING IN MILS PER YEAR
NEW ORLEANS, LA.
SALT LAKE CITY, U.

FIG. 15—RELATION OF SOLUBLE SALTS IN SOIL WATERS TO RATES OF CORROSION AND PITTING

no observations of the variations in soil conditions from day to day were made. Detailed data from which a theory of corrosion could be constructed are therefore lacking. To supply some of these data a number of laboratory studies were undertaken in the hope that a better understanding of the problem could be obtained.

A review of a considerable number of chemical analyses of soils indicated that under many conditions the tests usually made did not furnish an indication of soil corrosiveness and soil analyses were postponed until it was better known what to look for.

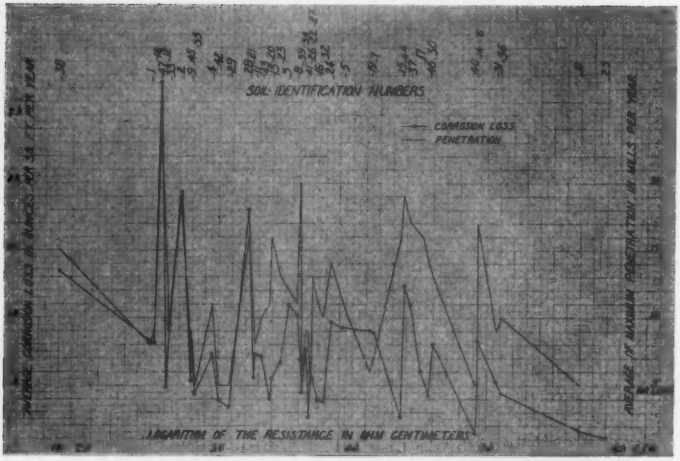

FIG. 16—RELATION OF RATE OF CORROSION TO SOIL RESISTIVITY

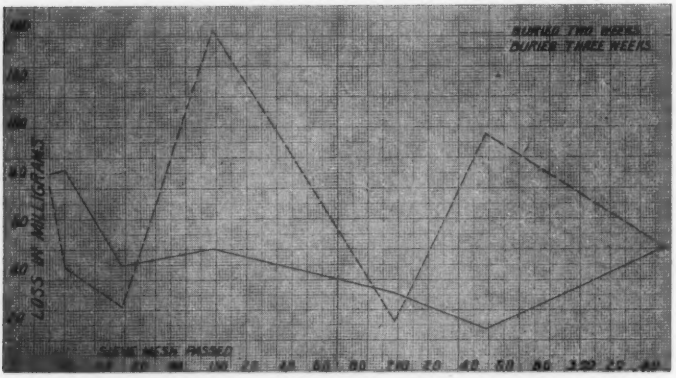

FIG. 17—EFFECT OF SIZE OF SAND ON CORROSION

A method of quickly determining corrosiveness seemed desirable. A study of the hydrogen ion concentration (acidity and alkalinity) in soils indicated that strongly acid or alkali soils were corrosive but that some other characteristic determined the corrosiveness of nearly neutral soils.

When the 1922 pipe specimens were buried, samples of each soil were obtained for future study. These samples have been used for determining their electrical resistivity when saturated with water and the amount of water required for saturation. A small piece of sheet steel was buried in a sample of each soil as a laboratory corrosion test for the purpose of comparing laboratory and field results and developing if possible a satisfactory accelerated test. The results of this work are incomplete but so far they are not promising. It appears that such tests are greatly influenced by the moisture and oxygen associated with the soil at the time the specimen is placed in the soil.

2. *Effect of Size of Soil Particles.* In this connection some of the results of the experiments to determine the effect of the size of the soil particles are of some interest.[4] Seven sizes of particles were used ranging from gravel and sand, passing a No. 8 sieve, to English china clay, passing a 350-mesh sieve. Ten per cent moisture was added to each of the materials except the coarsest which would only retain about 4 per cent. In cans of these materials were buried carefully cleaned and weighed strips of thin sheet steel after which the cans were sealed. The losses after two and three weeks were not entirely consistent but showed a tendency to decrease slightly with the size of the particle as is shown in Fig. 17. The irregularities in results may have been caused by differences in the compositions of the materials used.

The point of greatest interest was the appearance of the corroded specimens. On the strips buried in the larger sized materials the corrosion took the form of more or less regular

[4] Credit is due C. D. Yeomans for the carrying out of most of the laboratory tests herein described.

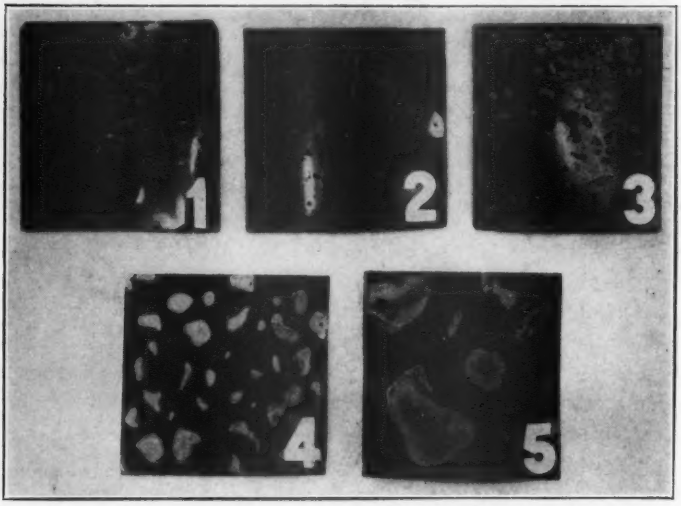

FIG. 18—EFFECT OF SIZE OF PARTICLES ON CORROSION OF SHEET STEEL—(1) CLAY; (2) FINE SAND; (3) COARSE SAND; (4) FINE GRAVEL; (5) COARSE GRAVEL

closed lines or rings with bright metal both inside and outside the ring. This is illustrated in Fig. 18.

It will be noted that the maximum corrosion did not occur where the oxygen was excluded by contact between the gravel and the steel but just outside this contact area. The steel in the coarser sand was covered by small rust spots while that in the china-clay showed rather large corroded areas adjacent to which were areas of similar size showing no corrosion. On the whole the test indicated a relation between the pitting and the contact between the metal and the material in which it was placed.

3. *Effect of Temperature.* The results of an experiment intended to show the effect of temperature are shown in Fig. 19. Thin sheets of steel were buried in cans of sifted silty clay soil from the Bureau of Standards grounds and four specimens maintained at each of three temperatures, 25, 57 and 85 degrees Cent.

Half of the specimens were removed after two, and the remainder after three weeks. The data indicate a tendency toward greater corrosion at the higher temperatures. This may partially explain the greater corrosion generally found in the southern states although other factors are probably of more importance.

4. *Extent of Protection due to Galvanizing.* The extent to which galvanizing protects a metal surface after part of the base metal has been exposed is of considerable interest. Mills[5]

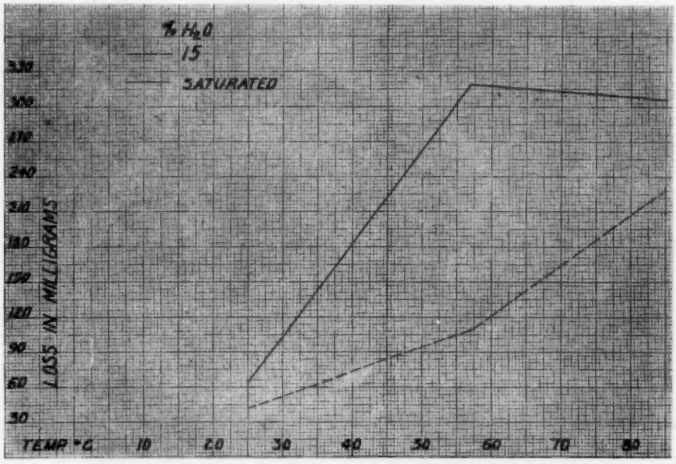

FIG. 19—EFFECT OF TEMPERATURE ON CORROSION

cites a condition in which a sleeve of zinc cast on a steel tube protects the tube in an oil well against corrosion for a distance of eight feet beyond the end of the zinc casting.

To determine the protected area on galvanized sheet the zinc was ground from a triangular area at one end of the sheet and the sheet placed in a vessel of tap water. Within two weeks rust covered the triangle to within about ½ inch of the galvanized surface. In examining this sheet the rust was brushed off. An

[5] R. Van A. Mills, Protection of Oil and Gas Field Equipment Against Corrosion, Bureau of Mines, Bulletin 223.

attempt to obtain another coat of rust failed although the sheet was replaced in the same water and later in dilute solution of sulphuric acid and in salt water.

Why the iron corroded at first and failed to corrode later has not been determined. The zinc was machined from a 17-inch

FIG. 20—EXTENT OF PROTECTION DUE TO GALVANIZING

specimen of 2-inch galvanized pipe to within two inches of each end and the pipe immersed in tap water. Rust formed to within about two inches of the galvanized surface. Fig. 20 shows three views of this pipe. It has been suggested that the extent of the protected area in the experiments under discussion depends upon the conductivity of the electrolyte.

5. *Accelerated Corrosion Test.* A little work has been done on accelerated or short-time corrosion tests and more will be done when other work permits. Accounts of more or less satisfactory accelerated tests have been received but the results of our limited experience with those we have tried do not indicate that they are altogether trustworthy. A little work has been done on the Putman method[6] of accelerated corrosion testing but as yet no satisfactory results have been obtained.

6. *Galvanic Currents.* In several locations when the earth had been removed down to the tops of the specimens tests apparently indicated small currents flowing between specimens. Conditions were therefore approximately duplicated by placing 2 specimens a foot apart in a box of moist earth. Measurements on the surface of the earth between the specimens indicated a current apparently flowing from one to the other. The nature of this current was revealed when the indication remained constant after one of the specimens was removed, i.e., the current flowed not from one specimen to the other, but between different points on the same specimen.

This is further illustrated by an experiment suggested by some unpublished work by E. R. Shepard, consulting engineer. A single large graphitic pit was formed electrolytically on the side of a section of 6 inch cast iron pipe. The pipe was placed vertically in a tank of tap water so that the pit was half immersed and measurements of the difference of potential between two non-polarizing electrodes 4½ inches apart on 16 pipe radii were made. Fig. 21 shows the magnitude and direction of the potential differences. These are of course only components of the local potentials due to the current flowing from the pit to the surface of the pipe. Similar tests with the pipe in moist earth gave similar results, except that probably on account of the greater conductivity of the soil the values were larger and the positive sector was smaller. It is evident that a current flowed from the pit to other portions of the pipe in accordance with the electrolytic theory of corrosion. The most interesting feature of the

[6] Sibley Journal of Engineering, vol. 31, pp. 188-190.

experiment is that the effects of this current covered such a wide area and could be so easily detected.

After two years the experiment was repeated. During this time the surface of the pit had taken up additional oxygen and had a dark rust colored appearance. The results of the test were similar to those obtained earlier except the direction of

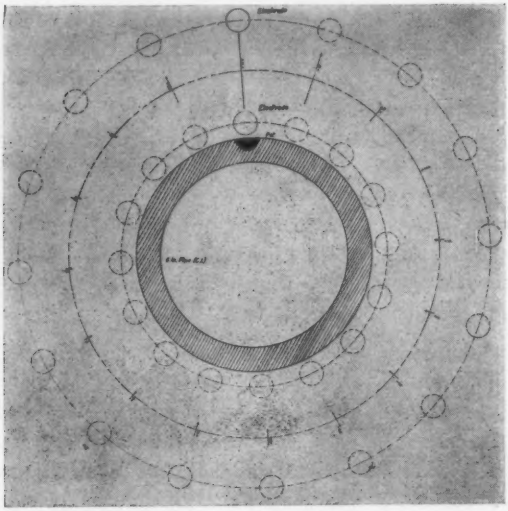

FIG. 21—GALVANIC POTENTIALS DUE TO CORROSION

the current was reversed. The surface of the pit was then scraped until most of the reddish discoloration was removed and the test repeated. The current was then found to flow from the pit to the uncorroded surface of the pipe as in the original experiment.

Thus it appears that the polarity of the corrosion product with respect to the pipe surface depends upon the degree of oxidation of the corrosion products.

VI. *Summary*

The results which have been discussed represent the earlier stages of the Bureau of Standards investigation. While the 1924 and 1926 results are, in general, similar, there are reasons for thinking that new factors may influence later results.

Both the 1924 and 1926 specimens indicate that the type of corrosion is in some way associated with the locality in which they are buried.

It has been assumed that this is due to some characteristics of the soil of the locality. Serious corrosion has been found in several localities and, on account of this, an attempt to associate corrosion with soil characteristics seems desirable.

The investigation of bituminous coating materials indicated that the thin dip coating under test furnished inadequate protection against severely corrosive soil conditions. A further study of protective coatings is needed.

While the corrosiveness of several soils must be recognized, attention should also be called to the fact that in the majority of soils the rate of corrosion is low and in some it is practically negligible.

There seems to be a tendency for the rate of corrosion to decrease with time in most soils and the rate of penetration of the pipe wall apparently decreases more rapidly.

On account of the possibility of the entrance of new influences as the specimens grow older, because of the apparently decreasing rate of corrosion indicated by the 1926 specimens and because of the large differences in corrosion of the different specimens of the same material under nominally similar conditions and the few specimens of each material so far examined, it is unwise at present to draw conclusions as to the relative merits of the materials under test or the probable life of any of them.

Synthetic Molding Sands in the Malleable Foundry

By F. C. Scheiber,* Erie, Pa.

During the past five years more research work has been done towards improving molding sand for the foundry than in all of its whole past history. The foundrymen are realizing that most of their difficulties and problems are in the make up and structure of nature's sands, and are not wholly due to oxides in the molten metal caused by poor quality of pig iron and rusty scrap.

Molding sand has been a bugbear for the foundrymen ever since the first casting was cast in sand. Sand wastes were enormous in order to keep their sand piles, as they believed, in first class condition. We think the molders of the past generation did very well. But then again they had plenty of time to take care of their sand, which was a large part of their job. Production was slow, sand was cheap and they had plenty of time for preparing it. But, as years advanced, times changed, production increased, good uniform sand was impossible to get. The molder now had little time for pondering over sand conditioning, with the result that this conditioning has been given over to foundry laborers.

The old molders died off, with them went the reliably kept sand pile and for years we have depended on inexperienced labor to make and blend our raw molding sand into a workable heap for the foundry. That this has been a complete failure some foundrymen will not admit, but it is nevertheless the case. Thousands of dollars have been thrown in the scrap heap on account of poor molding sand. Our good and intelligent molders and apprentices have been driven from our foundries on account of having to stand the losses of castings due to sand conditions. New surface sands full of organic matter cannot be transferred from the sand bank and dumped on our molding floor with expectations of making good castings.

*Superintendent Malleable and Alloy Foundries, General Electric Co., Erie, Pa.

We read an interesting article in the Industry Illustrated Magazine by Francis Juraschek, from which we quote as follows:

"Stop building concrete walls inside your boilers. Why feed water treatment pays." This article goes on to say, "Water is H_2O, says the chemist, and that is a correct definition, if you mean pure water. But where will you find pure water in Nature? Water from rivers, from lakes, from springs and from wells, is far from pure. In a 100 H. P. boiler evaporating 400 gallons of water per hour, water with only 15 grains of scale forming minerals per U. S. gallon will deposit 20.6 pounds of scale in 24 hours."

It would be suicide to feed unfiltered water to our boilers, and so it is the same with molding sand and our foundries. Surface sand from the natural deposits may be likened to unfiltered water, and is not good for foundry use before treatment.

Sands Should Be Treated Before Using

After years of experimentation and of many failures, the writer has come to the conclusion that all molding sand should be treated before being used. Molding sand in its natural state is saturated with foreign matter and flame producing elements which if not removed before molding will cause blows, washes, cracks, rough spots, cuts, scabs, blisters, excess shrinkage and prevent the free escape of gases.

The greatest waste in a foundry is discarded sand, which after once being used is thrown out on the dump at a cost of $2.00 per ton to carry it out of the foundry. Along with it goes iron scrap of good value. If we can only reclaim the value of this material which is now classed as refuse, by running it through a reviving system, we have for a base a sand free of all foreign matter which will produce, if treated rightly, a better sand for all classes of molding than when it was in the green state. Some foundries make a practice of putting this sand back in the sand heap without cleaning. This should not be done as the silt in it causes the sand pile to decrease in permeability, which lack of permeability in the sand causes an increase in defective castings.

Old Core Sand Makes Excellent Base for Molding Sand

Take the burnt out molding sand which clings to the hot castings on the shake out and the used core butts and old cores which are hooked out of the sand after pouring and run this material through a cleaning process. Can you get any better sand as a base than old core sand with its perfect round grains which prevent interlocking when rammed in the mold, thereby guaranteeing a free vent for the escape of gases?

Is there a cleaner sand to be found for molding purposes than this sand high in silica content? Yet, this sand was formerly thrown on the dump. You can take this valuable sand after cleaning and blend it with your discarded molding sand and make any kind of a new molding sand you need for medium, light or heavy work. And it will be a sand a molder can depend on. It also will be one which will cut your foundry defectives to a minimum.

For the past two and a half years we have been using nothing but prepared sand in our malleable foundry at Erie, Pa., and the results have proven very satisfactory. Our losses have decreased beyond expectation. Our molders are highly pleased with the conditions and when your molders are pleased it is half of the battle. The appearance and surface of our castings have improved and molding conditions in general are greatly improved.

Treating Core Sands for Molding Purposes

Treating core sands for molding purposes is a simple one provided the sands are put into shape for such treatment. For instance, the sands used should be of uniform size, round and of good sound structure such as Ottawa or Michigan drift sands. The sand can be used first for cores and after casting, all core butts, scrap cores, core room sweepings and discarded sands should be run through a barrel type furnace with heat high enough to burn out all core binder and water crystals on the surface of each grain in order to make the surface clean and rough to hold the clay bath. The heat should be high enough to break down all cores without a grinding operation, as grinding destroys the round sand grains and makes sharp grains which are a detriment to a good molding sand.

All sands should be screened in the dry state and scrap removed, and all excess dust and silt should be eliminated by air separation before mixing. By doing this we remove 90 per cent of our molding sand troubles.

A mixing machine of a large enough capacity should be used for mixing the molding sand to give it the required blending, or, in other words, distribute the clay evenly around each grain of sand without breaking up the sand grain structures. This operation is important to get good results, for where we substitute a grinder or any other kind of method to do this work it will prove a failure.

Selection of Proper Clay Important

The proper clay to use for the bonding purposes in molding sands is a problem and should be given much thought and study; for on the clay used, hinges the success of this process. First, we should use a clay with high heat resisting qualities and containing over 60 per cent of colloids. For good molding sands depend not only upon the colloidal content in the clay, but to the extent to which this content is held under various conditions of heat.

The clays used should be pulverized to a fineness of 40-mesh or better, and made into an emulsion bath and have this bath worked in such a manner that the disruption and dispersion are so complete that all are changed into a colloidal mist.

Dry clay should never be added to the sand heap, for it is impossible to distribute it evenly over the pile and coat each grain of sand with the desired amount of clay without forming clay balls and clay pockets which are detrimental to good foundry practice.

Use of Glycerine Prevents Drying Out Too Quickly

For a long time the writer has had difficulty with the sand drying out too quickly both in the pile and in the molds. This was found to be true in large molds where the drag and cope were exposed a long time before closing, and the molder had trouble in slicking and patching on account of this dryness. This difficulty was corrected by the use of a small amount of glycerine in the emulsion bath. This is something new in the

foundry industry and will keep the sand moist for hours or days, according to the amount of glycerine used.

Care in Mixing Process Needed

Great care should be used in the mixing process. The material should only be milled long enough for complete distribution. To the treated sand is added enough coal dust to produce a mild smudge when coming in contact with the molten iron. This insures a smooth casting easily cleaned. A small part of corn flour for green bond should then be placed in the mill and milled for two minutes, to this mixture then the clay-glycerine emulsion bath is added and again milled for three minutes. This newly prepared sand should then be riddled to give it a light, fluffy and well aerated product before beginning the molding operations, and this sand should be used in making the entire mold.

Results Have Proven Satisfactory

Molding sand prepared in this manner is a free venting sand with sufficient outlet for the steam and air generated by the molten iron entering the mold, which guarantees a good sound casting.

It is a great mistake for foundries to use a good facing sand of a fraction of an inch in depth next to the pattern and back this up with old heap sand full of silt and expect a good casting.

A good grade of molding sand made as described can be used for all classes of work and will produce good sound castings with a better surface than a mixture of several grades of natural sand. The reason for this is that the sand grains are all uniform and can be rammed to the surface of the pattern which produces a smooth surface and clean pattern draw. This method will fit in very nicely where foundries have sand conveying systems.

We believe the time is at hand for the foundries to install their own sand handling and sand treating machinery to insure a good reliable product. A product which will produce good castings free of blemishes, which in turn automatically increases production and makes use of good materials formerly thrown on the dump. All of this means a great saving in money and many worries for the foundry superintendent.

Discussion

H. B. Hanley: Does the author use any modern sand testing apparatus in an effort to control the properties of the prepared sand he is now making at Erie?

F. C. Scheiber: Yes, we have a Dietert system in our Erie works, and we make a daily test of our sand piles. Then we take a daily analysis of our batches as they come from the mixing machines.

H. B. Hanley: Another point I would like to ask that has to do with the use of glycerine, which I notice you have come to in your prepared sand. You argue at length about uniform sands being very desirable, which is shared greatly by others in the industry. But I would like to ask you if you did not find in the use of synthetic sands that they had a marked tendency to dry out quicker than natural sands? Am I right in supposing that this rapid drying practically forced you into the use of glycerine?

F. C. Scheiber: Yes.

H. B. Hanley: Is this just one type of sand that you are using now, or am I to understand that you are using several types?

F. C. Scheiber: We have what we call three grades.

H. B. Hanley: Are they all sensitive to water?

F. C. Scheiber: Yes.

H. B. Hanley: We find in our daily control work in our laboratory that synthetic prepared malleable sand is very sensitive to water. It tests out better in bond and permeability where Michigan City is the base, when there is 6 per cent water content. Below that figure permeability and bond are very seriously affected.

F. C. Scheiber: We keep ours above 5 per cent moisture.

H. W. Dietert: How strong do you make the new rebonding sand? You give the strength figures of heap sand and then the sand that you add for bond.

F. C. Scheiber: We have a bond which averages about 130 on the bar test.

H. W. Dietert: What is your heap sand? Is that 130?

F. C. Scheiber: The property is about the same. The average is around 130.

H. W. Dietert: If the two are the same, the portion of new bonding material must be high. The amount of coarse sand mixed with clay bond must be fairly high. If you add new sand, your rebonded sand is 130 and your heap sand is 130, the increase produced by the rebonded sand would be very slight, would it not? It would not raise the strength of your heap sand.

F. C. Scheiber: Our heap sand does not reduce very fast where we keep continually adding anywhere from three to four wheelbarrows a day to our heap sand, which keeps the bond up to around 130. We don't give it a chance to deteriorate.

H. W. Dietert: I think that is quite different from some of the other users of clay bonding material. Some people make the practice of stepping

up this rebonding sand pretty high. In other words, they like a high bonded molding sand. If a heap of your molding sand was 130, they would add about a 230 sand.

F. C. SCHEIBER: We figure in adding a high bonding sand you can't evenly distribute that through the sand pile. To each 1,680 pounds of sand we add 157 pounds of clay, the clay being in the dry state.

H. B. HANLEY: Have you observed any breaking down of the silica grain structure under the heat treatment and could you give us some idea on the temperature of heat treating operation?

F. C. SCHEIBER: We find it does not break down the structure whatever. The temperature for the furnace will average between 400 and 500 degrees Cent.

H. B. HANLEY: I would like to know how many tons of this prepared sand can be made in a day for a shop like yours.

F. C. SCHEIBER: We are producing at the present time 20 tons, I believe, around 20 to 25 tons of this sand per day.

MR. RUNNION: What is the refractoriness of the clay, the fineness of it, the amount of colloidal material, which seems to be very important.

F. C. SCHEIBER: We have no written specifications on clays as yet. We have been experimenting, using several different kinds of clays. At the present time we are using in our Erie foundry three grades. We like to have a total silica content of around 53 to 55 per cent. Of course, we try to cut down the impurities as low as possible. We are getting a fairly good clay.

MR. RUNNION: About what percentage of the total amount of sand used in your foundry is treated each day?

F. C. SCHEIBER: We have between 300 and 350 tons of sand in our foundry and treat about 25 tons a day.

F. M. ROBBINS: We have been for about a year trying Mr. Scheiber's methods in our foundries, at first very gingerly, one heap here and one heap there, and have gradually worked into it. With the heaps that we have worked out we have found a decrease in molding losses, a decrease in cleaning cost, both in the hard iron and in the annealing, and we have made a substantial saving, not only in our laboratories, but in our sand cost, so that we find that the system as far as we have gone works beautifully.

F. C. SCHEIBER: We have found out in our malleable each 1 per cent reduction in our losses represents $1,000 a month. So that adds up quite a little.

H. B. HANLEY: I would like to ask if it would not be perfectly safe to leave the impression with those present that in taking a step of this kind that it is absolutely essential and important that you go into the equipment end of it, to assure yourself of the success that you are putting across in this paper?

We don't want to lose sight of the importance of that end of it. I am close enough to the malleable industry to realize that enormous sums of money have been spent in the development of synthetic sands and the

great sum has been spent largely in the mechanical equipment end of it. We have the knowledge but we also want to face the facts and recognize the importance of the necessary kind of equipment, and that does cost real money, and perhaps not all small jobbing shops are prepared to spend that money.

H. W. DIETERT: I am beginning to feel possibly a better finish comes from using sands with a lower bond. Mr. Scheiber says he gets a bar test of 130 grams. A lot of foundries are operating with a higher bonded sand. If the sand is fairly well bonded, just so it will stand and not drop, you are bound to get a better finish. If the men who are still staying with the good old molding sand would use less bond they'd get a better finish. If I were molding I would run my bond up so I would not have to ram it so hard. The tendency is to work too high a bond. Clay sticks to the iron. The higher the clay is the more it cinders or fluxes to the iron casting.

H. B. HANLEY: I remember very well the summary I wrote up at one time stated that the sand bonded just enough and not too much, just so it would hold together, always turned out the finest looking castings. I followed this up in the steel casting industry, and inquired among some hundred or more steel foundrymen, and they stated most of their troubles which could be cured quickly were cured by lessening the clay content of steel sands, and bringing them more closely under control, which goes hand in hand with the reasoning Mr. Dietert has given us.

Just one other point that is troubling me a good deal, and that is the condemnation Mr. Scheiber has given to molding sand. It would not be quite fair to sit here and take it just as given. I wish he'd enlighten me a little more on the organic matter natural molding sands carry, and why surface sands are condemned.

F. C. SCHEIBER: I am not condemning a good molding sand, but I am condemning some of the sand being delivered into our foundries. You go out to the sand banks and they sometimes get into the shale and top soil, which is high in vegetable matter. This, then, is what is often delivered into our molding shops. If the molding sand man uses more care in that maybe possibly we can get a better molding sand in our shops, but the present practice some are using I condemn.

MR. HEISE: I want to ask if molding sand is really condemned because we are trying to find a substitute for molding sand? I don't believe it, myself. I am sure Mr. Scheiber does not condemn the sands altogether, except the sands that contain the impurities that he speaks of.

H. W. DIETERT: It states here you can make medium, light or heavy work and I would like to know how Mr. Scheiber gets his medium, heavy and light molding sand.

F. C. SCHEIBER: In our screening operation we get our heavy sand from that which drops through the No. 8 mesh and stays on the No. 60. What goes through the 60 and stays on the 80, goes into lighter work. Then, as I say, the 7 per cent of sand that we get out of the silt, which goes into separation, is placed in sand for the real light work. In that

way we mix the different grades to answer each different class of casting. Then for our lighter work, we use naturally less sea coal.

H. W. DIETERT: I believe the right way in adding sea coal is to add the coal to all of your sand, not make a special batch and put it on the skin of the pattern. Make all sand a good facing, for it is faster than the other way, of making a special sand.

MR. WATERBURY: I was interested in Mr. Dietert's suggestion that all the sand should be facing rather than part of it, because we have six different kinds of facing. We are making at present six different batches of sand, which is probably more than necessary. I think that I would enjoy hearing anybody here that can talk on eliminating so many different kinds of facings.

H. B. HANLEY: I can add a little information along that line. The Symington Company a few years ago figured out it would be very economical to add the sea coal to all the sand piles and make a better casting surface finish. At that time natural sand was spread throughout the foundry. At the end of six months the experiment proved unsuccessful. There was no mystery back of it. The sand was too fine to carry sea coal and the fine sea coal they added simply put in so much more filler and lowered the permeability and caused trouble. Now the foundry has changed over and synthetic sand is used there and practically everything is put through a sand treating system and that type of sand does carry grade E sea coal without any trouble at all.

H. W. DIETERT: I believe that sea coal—I should not state definitely sea coal, but facing material—can be left out entirely, providing you run your sand low enough in bond and then ram hard. We have one plant that is running without any facing material whatsoever.

MR. YEARLEY: I would like to know how, if we are not going to use any facing material, we can maintain a sand heap where we are making a job, say, for example, one that has cores in it that weighs from twenty to thirty pounds, and the greater part of that core sand goes back into the sand heap out of every mold. If we are not going to use facing material how can we maintain that sand heap and get a good finish?

F. C. SCHEIBER: I believe in that case, where you are using a pattern in the sand heap that contains large cores, that you will have to turn over your hand heap more often, changing it. We find out that where we run a job with a large core and we can't get the core out of the sand pile without crumbling and mixing in with that sand, that we have to change the heap more often. That is, take the sand pile out twice a week. Sometimes we have to take it out every other day. You have to watch that. Your daily tests will show what is necessary.

B. D. FULLER: In my position as Chairman of the Molding Sand Research Committee I hesitate to say anything which might be considered as criticism, but I think it is unnecessary for me to say to you gentlemen that in that position I certainly stand for progress, and I think that in all fairness to the men who are using molding sand and to the producer, and I

am one of them, that the statement in this paper that, "As years advance, times change and production increases, good uniform sand is impossible to get." The word "impossible" covers a lot. I think that the author in all fairness should qualify that statement a little.

F. C. SCHEIBER: In getting out this paper we have only taken into consideration our immediate vicinity, and the possibility of getting the sand into our plant. Of course, I suppose we could get good sand from some other district by paying a high price for it. We figure that we can make it in our own foundry to satisfy ourselves at a cheaper price, which is around $2.80 a ton.

MR. HEISE: I believe if Mr. Scheiber will just give us an idea on how his scrap is running it will either satisfy or dissatisfy a good many as to the feasibility of making synthetic sand.

F. C. SCHEIBER: While using the natural sands—possibly, as I say, we did not get the right kind of natural sand or we were not using the right supervision, but we were using all we had at that time—during the year of 1919 our scrap ratio in our malleable foundry ran around 18 per cent. That does not mean on all production work. Our foundry at Erie handles all the malleable castings production for our allied plants, and included in that are castings ranging from a fraction of an ounce up to 400 pounds. Our orders run 42 per cent less than 50 molds, 26 per cent less than 10 molds. In the past year, 1926, our average loss was 8.6 per cent, covering the whole foundry. On repetition work, what we call machine work, which is what the average malleable foundry handles, our production loss was 3.6 per cent. Our machine shop loss has been reduced from 5 per cent down to less than 1 per cent. So what shall we lay it to? We lay it to the good materials that we are using, included with the supervision. So I think with the reduction in our loss, which as I say, amounts to $1,000 a month for every 1 per cent reduction, it is a paying proposition.

MR. MALLSBERGER: I would like to ask Mr. Scheiber if that $2.80 a ton is the cost of sand, or if he has ever worked out the cost per ton of casting, what is the sand cost per ton of casting?

F. C. SCHEIBER: That $2.80 is the total cost of manufacture of sand distributed to the molders' floor, interest on investment, depreciation and upkeep. Those other costs will be gotten in a short time.

E. F. WILSON: I would like to ask if any member has any ideas about the fineness of sea coal that is used. In our own foundry we are using sea coal from the pulverizer, the same we use for powdered coal. There are other foundries which make a separate grinding for sea coal used as facing.

F. C. SCHEIBER: I can tell you what we are carrying out at Erie. There are some foundries using a coarse ground coal at Erie. We have our own pulverizing plant; we have a 200 mesh which we furnish the annealing furnaces. We use the same coal in our facings.

Core Oil Specifications

By V. A. Crosby,* South Bend, Ind.

This paper is written from the production foundry viewpoint, and without much or any regard to the manufacturing problems of compounding the oil. The writer wishes to casually mention, in the beginning, that neither he nor any of his associates are core oil experts. It is hoped that the presentation of our method of securing uniform core oil without resorting to trade names may be of interest to those who have been laboring under a delusion relative to core oil.

Probably less has been written about core oil and core binders than most any other phase of the foundry industry. This is not at all peculiar if one considers that technical men in the foundry are a comparatively new thing, and that very little thought was given to the idea of determining relative quality of these materials until the last few years.

H. L. Campbell, of the University of Michigan, made quite a study of commercial core oils along with linseed oil. I was very much disappointed to note in Table 1 of Campbell's paper[1] that samples E, O and R show very abnormal analyses. We are not surprised that he arrived at the conclusion he did, with the chemical analysis he had to work with. Table 1 gives the data of Campbell's paper to which we refer.

Table 1

Oil	Iodine No.	Unsaponifiable	Iodine No. of saponifiable matter would have to be:
E	123.5	70.33	401
O	151.0	71.50	520
R	157.0	54.30	370

It is quite obvious that these analyses are wrong and that the iodine numbers are high. We have had a few samples of rosin which ran up as high as 265 iodine value and the highest value on any drying oil was a sample of raw Perilla oil at 208.

*Technical Director of Foundry Operations, Studebaker Corp.

[1] *The Qualities of Commercial Core Oils*, Trans. American Foundrymen's Assoc., vol. 53, p. 73.

The degree of unsaturation in an oil can be measured directly by iodine absorption, and, therefore, the iodine value indicates directly its drying potentiality. From this, the importance of iodine value in drying oils becomes very evident. Table 2 gives iodine numbers of the most important industrial drying and semi-drying oils.

Table 3 illustrates, to a degree, how iodine absorption, breaking strength and price go together. The prices of these oils are

Table 2

Oil	Iodine Number	Saponification No.
Perilla	199 to 208	189 to 194
Linseed	170 to 192	189 to 194
Chinawood	159 to 168	190 to 194
Menhaden	139 to 172	189 to 193
Sunflower	120 to 135	188 to 194
Poppy	134 to 152	190 to 197
Soya bean	122 to 130	190 to 193
Corn oil	121 to 131	189 to 192
Cottonseed	100 to 121	191 to 196
Rape seed	95 to 106	167 to 179
Mustard seed	96 to 122	172 to 180
Peanut	83 to 105	186 to 196
Sesame	103 to 117	188 to 193
Rosin	200 to 265	145 to 170

Table 3

No.	Iodine No.	Break Test,* Pounds
1	173.2	303
2	167.0	292
3	155.1	266
4	144.2	232
5	132.4	230
6	125.5	168
7	113.0	140
8	97.0	101

*The break tests were made with Olsen automatic briquette testing machine. Briquettes were made by hand ramming—the same operator doing all ramming. The tests shown in the above table are averages of nine briquettes baked at 405 degrees Fahr. for 45 minutes at heat. Temperature variation being + to —5 of the desired temperature of 405 degrees Fahr. The mixture was 1000 grains Michigan City sand, 80 grains water, 14 grains oil. The average grain size of the sand was 70 mesh.

from high to low as shown by the numbers of the oils in Table 3, No. 1 being highest priced.

After very careful and complete chemical and physical analysis of core oils for a period extending over about two years we evolved a chemical specification for core oil which has been in effect about one year. We do not insist that this is a special core oil, nor one with peculiar merit, but we do know that if the

oil meets the specifications we will have no trouble with its use, regardless of who makes it, or where it comes from.

The specification is given in Table 4.

Table 4

STUDEBAKER SPECIFICATION No. 39—FOUNDRY CORE OIL

Core Oil Must Conform to the Following Requirements as to Chemical and Physical Properties

Specific Gravity	0.9310 maximum at 60 degrees Fahr.
Flash Point	165 to 195 degrees Fahr.
Fire Point	180 degrees Fahr. to 210 degrees Fahr.
Iodine Number	155 minimum.
Saponification Number	148 minimum.
Acid Number	34 to 41.
Color	Light clear amber through half section.
Odor	Positively not fishy.
Gallonage	Shall consist of 231 cubic inches at 60 degrees Fahr. or actual weight per U. S. Liquid gallon at 60 degrees Fahr.

The purchaser reserves the right to subject each shipment when received to the above inspection and tests. Failure to pass any of them may be cause for the return of the shipment for full credit plus carrying charges both ways.

This core oil may, or may not, be the best oil possible to buy for the money; but we know it is a high grade oil, and that it gives perfect satisfaction as far as workability in the core boxes, the quick baking time, the thoroughness with which chunk cores are baked, and a minimum amount of obnoxious odors during baking of cores and pouring of castings; and core sand mixtures running 120 to 1 speak for themselves so far as strength is concerned.

We specify gravity because it is one way to hold the rosin content down. We mention flash and fire point because we desire a kerosene mineral oil or light furnace oil. Someone may wonder if he could get by in using a paraffine oil or some heavy oil and just inject a small amount of kerosene to get the flash and fire determination right, and to this I would say, no one in the core oil business would be quite so foolish because kerosene is the cheapest clear mineral oil available. The iodine number is mentioned because strength is the big factor and, along with other

things mentioned in the specification, it is positively indicative. Saponification number indicates amount of animal oil or vegetable oil or both present. We specify acid number and watch it very closely. We have had complaints from oils which run higher than 41, also from some running much lower than 34. We think there is a happy medium in a compounded oil of this nature and we believe it is around where we have specified. Color is mentioned because it places all vendors on the same footing, in that they must use a clear oil and H-grade rosin. A dark oil would permit the use of cheaper rosin and linseed foots to a degree and the latter would be undesirable, because of the stickiness in the boxes. It is quite obvious to anyone why we demand no fishy odor in this oil.

We do not make break tests (any more) to determine the value of a core oil. We believe that when all the errors encountered in making and baking briquettes are considered such as, (1) dye absorption of the sand, (2) grain size of the sand, (3) mixing and ramming of the sand, (4) ventilation and baking of cores, and (5) temperature control of oven, it becomes evident that the logical way out is to take the bull by the horns and do some real honest-to-goodness exact chemical analysis.

In conclusion we wish to state that a core oil specification is just like a steel specification. You would not think of buying steel bars on a carbon specification alone, neither would I attempt to buy core oil on an iodine number alone, but as in steel, all points must be considered and then an intelligent consideration of its real worth can be ascertained.

We wish to acknowledge the assistance Spencer-Kellog & Sons, Inc., of Buffalo, N. Y., and the Werner G. Smith Co., of Cleveland, Ohio, gave our laboratory when we were in the initial stages of our investigation.

Discussion

V. A. Crosby: The main idea in writing up a core oil specification is to get something that is entirely uniform, so your piece work prices and your production rate in a large core room can be maintained on a steady basis. In the past we had a large amount of trouble with oil being sticky one day and the next week it would be all right. One week it would work out a little better than it did another and we couldn't get down to any

reasonable piece work figure. If we set a production rate and the oil was sticky, the men couldn't make any headway, and if it worked well, the fellows made an unusually high rate.

I have had occasion to test out some core oils where some of the manufacturers thought they could get by by using a lot of rosin and adulterating it a little with kerosene and a certain amount of linseed and meet the iodine and saponification tests. We have found out that we can catch them very easily on the acid number of the oil. If they attempt to neutralize the acid limit or anything like that, they immediately lower the saponification number and you catch them on that. If they don't do anything to it, we catch them on the high acid number.

I had occasion to check an oil not long ago where it met perfectly everything in this specification except the acid number. The oil was very sticky in the boxes; we knew there was something wrong with it, because I had given it to the core room superintendent shortly after I got it and asked him to determine how sticky it was. He ran it along with some other oils and you could get about one core or two cores out of a box and then you would have to clean it, whereas with the regular runs we were getting 18 to 21 cores. The acid number was about eight points high. The iodine, saponification, gravity, flash point, color and odor were all right. I mention that because you have to consider everything if you are going to get anywhere with a core oil specification.

CHAIRMAN J. W. BOLTON: Some years ago most of us believed that the only real oil was a pure linseed oil. Subsequent work has shown that the use of thinners, such as kerosene, or a judicious amount of rosin, do not materially affect the properties of the oil in so far as its strength is concerned, and it makes the oil better for general commercial practice. This fact was recognized some time ago by some of the leading manufacturers of core oils and a few of them not only added judicious amounts but they went very far the other way, because some of the materials they were adding were cheaper and made them adulterations. By this test we have a practical way of limiting the amount of material that can be used to improve the properties of the core oils.

H. L. CAMPBELL: In the paper which has just been presented to us reference is made to the results of data on core binders which was published several years ago. When we first began our studies of core binders at the University of Michigan, particularly in relation to core oils, we thought perhaps it would be possible to get at the characteristics of the different core oils by measuring the properties of the oils themselves, because these properties are given in the A. S. T. M. specifications for the pure oils. We collected a large number of commercial core oils and made an investigation and determination of the chemical and physical properties of these commercial core oils, the purpose being to determine if it is possible to measure the bonding characteristics of the core oil from any chemical or physical property of the oil.

After thoroughly covering the entire field of chemical and physical properties of these large number of commercial core oils and comparing this information with the data obtained in measuring the bonding property of the oil when used in cores, our conclusion was that there was no relationship between the chemical and physical properties of the oils and the use of the oil as a binder in dry sand cores. The information was plotted in the form of a graph indicating degrees of quality. Not a one of these chemical or physical properties of the oils indicated any law or tendency that these properties had any relationship to bonding strength.

Now, the reason for our finding was that commercial core oils are not pure oils. If you have pure oils, possibly you may be able to use chemical or physical tests. I understand, though, that the American Society for Testing Materials specifications for even pure oils have to be changed periodically, depending on the seasons of the year, when the flax seed has certain characteristics, due to certain climatic changes or something of the sort.

The very fact that the Studebaker laboratory cannot confirm or agree with our data published and prepared by a specialist, a chemist, on properties of these oils, the very fact that they cannot agree with those values is proof in itself of the difficulty of trying to get two parties together on chemical specifications of a core oil.

These methods of determining the iodine values, non-saponifiable value, index of refraction, etc., these other chemical and physical properties are very difficult to determine accurately, extremely difficult, requiring a specialist. We do not have oil specialists in our foundries today. It is rare to get hold of a man who has the ability, the experience and the practice to measure accurately these fundamental characteristics of pure oils, and consequently, the impracticability of having a chemical or physical specification for core oils.

The case of core oil is similar to the case of Portland cement. Portland cement is used as a bond for sand just the same as core oil is used as a bond for sand. You can imagine the difficulty of the Portland cement manufacturers specifying only chemical properties of Portland cement. It would not answer the purpose. Portland cement is purchased to bond sand just for the reason that core oil is purchased to bond sand. Methods are now available for determining the important physical characteristics of cores by which you can get at the value of the oils used.

I notice on page 150 the statement is made that strength is the big factor. Well, why not measure strength? We buy core oils to bond sand. Why not measure bond? You can measure physical properties of core sand mixtures much more easily than you can ever measure iodine value or non-saponifiable value or acid number or these other characteristics, if you have to measure all of those properties. Consequently, the difficulty of using a chemical specification for core oils. Physical properties tell you definitely the purpose for which you purchase the oil, and as far as we have been able to determine, as far as our research studies go on the characteristics of

binders, it seems to us that the proper method to get at the characteristics or to base specifications is on the physical properties of the binders when used in dry sand cores.

V. A. Crosby: I would like to take exception to what Mr. Campbell said about putting anything in this core oil specification. It is true you can put anything into any core oil, but if you write up a specification, you vastly limit the things you can put into it. I would leave that right up to the core oil manufacturers themselves as to just about what they can put in this core oil specification and get by with it. I think there are about half a dozen of them who have been working rather diligently on it and they have found that they can't put anything in it and get by with it.

Offhand, I would say that you cannot vary very much from 60 per cent linseed, 20 per cent rosin and 20 per cent kerosene and be able to get by with it. We have mentioned gravity, we have mentioned flash and fire, we mentioned the color. Now, when you specify color, that rules out a lot of stuff that can be used as an adulterant, such as foots, asphalt base crudes, fish oil and a lot of other stuff like that. We have said color and odor and gravity. Now, saponification and acid number and iodine number tell you how much animal and vegetable oil can be in it; it tells you how much rosin is in it, and your iodine number tells you the degree of the vegetable oil that is present. You couldn't use corn oil, you couldn't use soya bean oil or anything like that, the iodine number is too low; you couldn't possibly get up to 155. And to get 148 saponification number, you would have to have right around 79 to 81 per cent animal and vegetable oil, such as either rosin or linseed.

I want a good, clear linseed oil for the base, and with it H-grade rosin, or it won't pass that light amber color. Somebody else will come along and use a black rosin in there and it is a lot cheaper. I am not saying whether it is just as good or not, but if he used a black oil, that will give him a means of covering up a lot of linseed foots if he wants to put it in.

Werner G. Smith: I don't think it is a good idea for sellers to intrude themselves in this kind of meetings, but inasmuch as this is a subject in which we are vitally interested, I am speaking extemporaneously and just as the thoughts occur to me. I heartily agree with Mr. Crosby in his attempt to draw up specifications on core oil. I believe the core oil manufacturers have gone far and away beyond the expectations of the foundrymen in the way of technically controlling their products. We all have laboratories, at least the larger ones, and technicians at the head of them that are specialists in core oils, and we think we know something about it.

We check our own oils pretty much along the same lines as Mr. Crosby does, and therefore any efforts that you fellows make to meet us on a common technical ground will advance this industry, and I am heartily in favor of his move in this direction.

Yet I want to make a few remarks about this on things that you should know. For example, his specifications may be all right for his foundry, yet it may not be all right for yours. We find that the automobile foundries for making jacket cores, etc., require a given binding strength. We find that they require certain baking temperatures, and the size of the core has something to do with the quality of oil required. We find an entirely different situation when it comes to making radiator cores. We find, for example, the radiator core requires a much higher percentage of rosin than an automobile cylinder shop. We find also a jobbing foundry that makes the various sizes of cores, some small and some large. Primarily, they are getting their greatest strength from the moisture absorbing binders and they want to use core oil primarily to retard the moisture absorption of the other materials. Therefore, it requires a given kind of core oil. So we can't in a meeting here adopt any specifications and make them applicable to all your industries. Every man has to work out those specifications for himself.

Now, when it comes to fooling you fellows with your specifications, no dependable core oil manufacturer has any disposition to do that; they want to work with you. We can take Mr. Crosby's specifications and beat him; I don't mind telling him that. But we can't beat him and hold his business, that is the whole thing; we can't beat him and continue to do it and give him satisfactory results. I can change his mineral oils on him and save a little money on his specification. I can put in some other kind of binders there and get by quite satisfactorily. But we don't do it because we consider his plant our bread and butter and we want to work with him, and that is the very reason that he writes up his specifications, and what knowledge is lacking in his specifications we supply and try to meet him on a common basis and give him what he wants. That is about the whole story.

Therefore, I think that he is on the right track, he gives his manufacturer a guide as to what he wants and his manufacturer improves on it as best he can and gives him the best product that he can possibly make, and there is some chance for us there. We can take his specifications and improve even beyond what he thinks we can do. That gives one manufacturer a better chance to get his business than the other, all because we give him a little better results than the other fellow.

The question of measuring the bonded strength in a foundry versus the question of chemical analysis has been brought up between Mr. Campbell and Mr. Crosby and it is a very interesting subject. I quite agree with Mr. Campbell in many ways, that, when everything is said and done, you are buying oil to bind sand, and that is the primary point and the point that should be considered first of all. But in making physical tests you will run up against a great many variables that Mr. Crosby mentions in his paper but doesn't bring out strongly enough, the question of atmospheric conditions, the question of the human factor in mixing your sand, your oil and your water together in the proper proportions, and in ram-

ming your cores. You can ram one core and you try to ram the next one the same, but it is almost impossible to ram them just exactly the same.

Another thing, I have never seen a core oil in my life that was subject to uniform temperature in an oven. It will vary at different heights and different widths in your oven, and when you accumulate all these possibilities for error, it knocks that binding strength pretty much to pieces. The way you bake these cores can fool anyone who makes that test a great deal.

Take an oil, a very high-grade oil, for example, as against a cheap oil, we will say an oil that is 25 per cent linseed, 25 per cent rosin and 50 per cent mineral oil and put that against an oil that runs 60 per cent linseed, 20 per cent rosin and 20 per cent mineral oil, put the two oils side by side, put them in an oven at 450 degrees temperature, put them in and pull them out at the same time, and you will get a much greater bond strength from your cheap oil than you will from your good oil, because the mineral oil leaves it quickly, to start with, and the rosin sets up fast, whereas an oil of 60 to 70 per cent requires a lot more heat to oxidize the base oil and turn it into a film. That is what you are after anyhow, you are putting in a liquid in your sand and you are trying to convert it into a solid in the oven.

Before closing I would like to make a remark on the question of gallonage that Mr. Crosby has brought up. He has one method of determining that and, incidentally, it made me feel a little cheap when he said we sell oil on the basis of 7½ pounds to the gallon whereas some of our oils run from 7½ to 8 pounds. Well, that it not our fault. We have our given materials, depending upon what goes in there, and if it weighs 8 pounds to the gallon, we are not attempting to cheat you, we are giving it to you just as it comes out. Linseed oil, as a matter of fact, was sold for years and years on the basis of 7½ pounds constituting a gallon. And why? Because it expands under heat and cold the same as steel does, there is a variation of 7 per cent in the volume of linseed oil with every 100 degrees of temperature; therefore, the linseed crushers years ago decided they had to have an arbitrary poundage as constituting a gallon. They carried that on for years and years and finally they decided that inasmuch as some of the other oils were sold successfully on the poundage basis, such as Chinawood oil, soya bean oil, cottonseed oil and a few others, that they would attempt to put linseed oil on the same basis; and that have been done, all linseed oil today is sold at so much per pound. To my mind, that is the simplest and most practical way to handle core oil. Buy it on the pound basis and then you follows determine when you are making your tests, if you want to, how the poundage of one core oil man compares with another, and that can be logged, as a matter of fact, very easily. But, at least, when you are once satisfied with an oil, then buy it on the pound basis and you will find that your running inventory at the plan will not show the variation that it is showing today.

I have in mind a very large customer to whom we have been selling

oil on the basis of 7½ pounds, and his inventory has been out repeatedly. Finally he took it up with us and wanted to know why. I said, "It is because we sell you 7½ pounds to the gallon and you measure out on the liquid gallon and you lose every time you measure out a gallon of oil."

"Well," he said, "how can we correct it?"

I said, "Buy it by the pound." He has done it and things are working out very smoothly.

R. B. SCHAAL: Mr. Campbell brought up the difficulty of making these chemical determinations as opposed to the physical tests. Now, it has been my experience in a great many different lines, not particularly along these lines but along quite a few other lines, that when we get into a plant where certain conditions obtain, the laboratory is used to make certain determinations in a certain way and a certain line of determinations only. Now, we will find that if this specification for core oil is made a part of the laboratory routine and it is worked upon continuously, there will soon be very little difficulty in attaining considerable accuracy in these results. In fact, I may say that there would be practically no difficulty in making these chemical determinations, and also the physical determinations he has listed here, after a certain amount of practice was had in making them. Therefore, I consider that it is quite feasible to make these chemical tests as opposed to the physical tests, and I also believe that they can be made much more accurately than can the physical tests.

The Effects of Moisture Absorption on the Properties of Dry-Sand Cores

By H. L. Campbell,* Ann Arbor, Michigan

In order to decrease the number of defective castings due to changes in shape of dry-sand cores when used in green-sand molds, it is imperative that the effects of moisture absorption on the properties of cores be definitely understood. An investigation has been made to determine the changes in strength and permeability of dry-sand cores when placed in green-sand molds for different periods of time. In general, cores must have sufficient strength to withstand handling after baking and to resist the forces to which they are subjected when used in molds. The exact physical requirements of any core are dependent upon all of the conditions under which the core is used. In most cases it is important to provide sufficient bonding strength in dry-sand cores to compensate for the loss in strength due to the absorption of moisture from the molding sand.

The characteristics of the materials used as core binders vary considerably. Therefore, it has been necessary to determine separately the changes in the properties of cores made with the different types of binders. Core binders may be classified into the following three groups: (a) those binders composed essentially of drying oils which harden mainly by oxidation, (b) the pitch and rosin binders which become hard when cooled from temperatures which liquefy the binders, and (c) those materials which are used in water solutions and become hard by the evaporation of the water. The water-soluble binders include flour from corn or wheat, sulfite liquors from paper mills, molasses, and dextrin. It is reasonable to assume that cores bonded with water-soluble binders would be affected to a greater extent by the moisture absorbed from green-sand molds, than would other types of binders.

*Assistant Professor of Metallurgical Engineering, University of Michigan.

The plan of this investigation was: first, to prepare test cores from definite core-sand mixtures; second, to bake these cores under specified conditions; third, to place the cores in green-sand molds for definite periods of time; and fourth, to measure the properties of the cores before and after remaining in the molds for definite lengths of time.

Core-Sand Mixtures

The core-sand mixtures from which the test specimens were prepared and the temperatures at which the cores were baked are given in the following paragraphs. From each mixture 25 transverse test specimens and 8 permeability test specimens were made in a uniform way on a core-making machine. Only washed and dried silica sand which passed a 60-mesh sieve (size of opening .0098 inch) and was retained on a 70-mesh sieve (size of opening .0083 inch) was used in the core-sand mixtures.* A small batch mixer of the paddle type was used in the preparation of the different batches. All of the cores were baked for one hour at the desired temperatures. The equipment and procedure for making test specimens, for measuring the transverse strength and for the determination of permeability were the same as used in previous investigations on the properties of core binders.[1, 2]

Mixture No. 1

In this mixture 1 part by volume of raw linseed oil was used with 50 parts by volume of core-testing sand. Water was added in the ratio of 4 per cent of the volume of sand. The cores were baked at 425 degrees Fahr.

Mixture No. 2

In this mixture 1 part by weight of wood rosin which was powdered to pass a 140-mesh sieve was used with 25 parts by weight of core-testing sand. Water was added in the ratio of 8 per cent of the volume of sand. The cores were baked at 350 degrees Fahr.

*Obtained from the Standard Silica Co., Ottawa, Ill.

[1] Campbell, H. L., "The Qualities of Commercial Core Oils," Trans. American Foundrymen's Association, Vol. 33, 1926, pp. 72-82.

[2] Campbell, H. L., "Methods for Determining the Properties of Cores Made With Cereal Binders," Trans. American Foundrymen's Association, Vol. 34, 1927, pp. 558-566.

Mixture No. 3

In this mixture 1 part by weight of powdered pitch was used with 25 parts by weight of core-testing sand. Water was added in the ratio of 6 per cent of the volume of sand. The cores were baked at 350 degrees Fahr.

Mixture No. 4

In this mixture 1 part by weight of cereal binder (a product from corn) was used with 50 parts by weight of core-testing sand. Water was added in the proportion of 4 times the volume of cereal binder. The cores were baked at 350 degrees Fahr.

Mixture No. 5

In this mixture 1 part by weight of wheat flour was used with 50 parts by weight of core-testing sand. Water was added in the proportion of 4 times the volume of wheat flour. The cores were baked at 350 degrees Fahr.

Mixture No. 6

In this mixture 1 part by weight of the product obtained by the evaporation of sulfite liquors was used with 50 parts by weight of core-testing sand. This binder contains the soluble resins extracted from wood in the sulfite process for producing pulp for paper making. Fire clay which passed a 200-mesh sieve was used in this mixture in the ratio of 6 per cent of the weight of core-testing sand. Water was added in the ratio of 8 per cent of the volume of sand. The cores were baked at 350 degrees Fahr.

Mixture No. 7

In this mixture 1 part by volume of blackstrap cane molasses having a Baume of 39.7 degrees was used with 50 parts by volume of core-testing sand. Water was added in the ratio of 4 per cent of the volume of sand. The cores were baked at 225 degrees Fahr.

Mixture No. 8

In this mixture 1 part by weight of dextrin was used with 50 parts by weight of core-testing sand. Water was added in the

proportion of 4 times the volume of dextrin. The cores were baked at 350 degrees Fahr.

Mixture No. 9

In this mixture 1 part by weight of dextrin was used with 50 parts by weight of core-testing sand. To these materials raw linseed oil was added in the proportion of 1 part by volume of raw linseed oil to 100 parts by volume of sand. Water was added in the ratio of 12 per cent of the volume of sand. The cores were baked at 400 degrees Fahr.

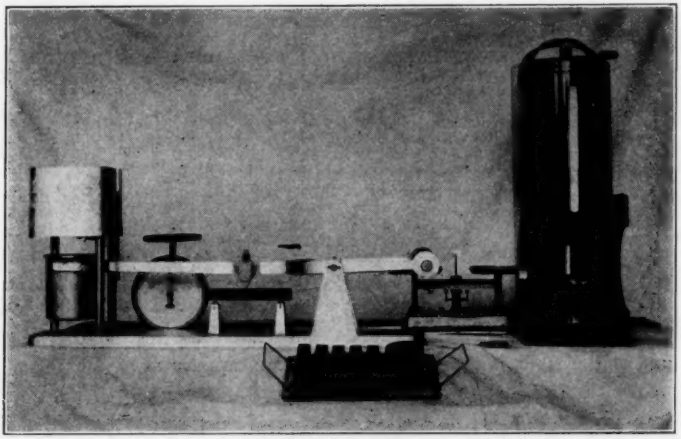

FIG. 1—TESTING EQUIPMENT USED IN THIS INVESTIGATION

Methods Used in Obtaining Data

For each series of tests, 4 molds were made in the foundry from iron molding sand after tempering with water and thoroughly mixing the heap. A pattern was used which produced a cavity 14 inches long, 10 inches wide, and 3 inches deep inside a two-part flask. A sample of the sand used in making each mold was taken for the determination of moisture.

Trays made of heavy wire screen were provided for supporting the cores within the green-sand molds. On each tray, 5 transverse test cores and 2 permeability test cores were placed, after

carefully weighing the cores. The cores were not allowed to touch the mold surfaces but were exposed on all sides to the atmosphere within the molds. The test cores were left in the closed molds for periods of 4, 8, 12, and 24 hours. At the end of each period, a tray of cores was removed from one of the molds. The cores were weighed and the transverse test specimens were broken on the testing machine. Permeability values were obtained before placing the cores in the molds and immediately after removing from the molds. The testing equipment used in this investigation is shown in Fig. 1. A tray on which are 7 test cores can be seen

Table 1

AVERAGE TRANSVERSE STRENGTH OF CORES BEFORE AND AFTER PLACING IN GREEN-SAND MOLDS

Mix No.	Binder	Before Placing in Mold, Pounds	After 4 Hours in Mold, Pounds	After 8 Hours in Mold, Pounds	After 12 Hours in Mold, Pounds	After 24 Hours in Mold, Pounds
1	Raw Linseed Oil	61	39	37	34	29
2	Powdered Rosin	31	29	29	28	26
3	Powdered Pitch	12	5	4	4	Less than 3
4	Cereal (from Corn)	52	18	13	11	11
5	Wheat Flour	19	7	6	4	0
6	Sulfite Liquor	55	22	13	8	4
7	Blackstrap Molasses	35	0	0	0	0
8	Dextrin	20	10	0	0	0
9	Dextrin and Raw Linseed Oil	63	34	12	6	Less than 3

in the foreground. At the left is the transverse testing machine and at the right is the permeability testing apparatus.

Effects of Moisture Absorption on Transverse Strength

The results obtained from the tests of cores which were placed in closed green-sand molds for definite periods of time are given in Table 1. Each value in the table is the average of the transverse strength of at least 5 test specimens. This information is representative of conditions affecting the use of dry-sand cores in general foundry practice. The average moisture content of the sand used in making the molds in which the cores were placed was 7.2 per cent by weight.

In order to determine whether the proportion of moisture in molding sands affects the changes in properties of dry-sand cores, some test specimens prepared from mixture No. 4 were placed in molds made from sands containing 5.1, 7.8, and 11.1 per cent

moisture. At the end of 8 hours, the cores were removed and their average transverse strengths were found to be 13, 12, and 13 pounds. These results indicate that the moisture content of the sand in molds does not control the change in strength of the dry-sand cores when placed in the molds. It is probable that the cavity within a green-sand mold soon becomes saturated with moisture, irrespective of the exact moisture content of the sand.

The average decrease in strength of each set of dry-sand cores after remaining for a definite period in a green-sand mold is given in Table 2. From these data it is possible to note the characteristics of the different binders when exposed to moist atmospheres. Cores made from mixture No. 7 were too soft to be handled after remaining in a green-sand mold for 4 hours.

Table 2

PERCENTAGE LOSS IN TRANSVERSE STRENGTH OF DRY-SAND CORES IN GREEN-SAND MOLDS

Mix No.	Binder	After 4 Hours in Mold	After 8 Hours in Mold	After 12 Hours in Mold	After 24 Hours in Mold
1	Raw Linseed Oil	36	39	44	52
2	Powdered Rosin	6	6	10	16
3	Powdered Pitch	58	67	67	75
4	Cereal (from Corn)	65	75	79	79
5	Wheat Flour	63	68	79	100
6	Sulfite Liquor	60	76	85	93
7	Blackstrap Molasses	100	100	100	100
8	Dextrin	50	100	100	100
9	Dextrin and Raw Linseed Oil	46	81	90	95

Mixture No. 9 was included in the series to ascertain whether raw linseed oil protects the water-soluble binder in the cores from rapid deterioration of strength due to the absorption of moisture. It was found that the strength of these cores decreased more rapidly than was characteristic of cores bonded with raw linseed oil alone.

Effects of Moisture Absorption on Permeability of Cores

The permeability of a core is the measure of the rate at which gases will pass through the core. Permeability values were obtained from cores bonded by different binders and exposed to green-sand mold conditions for different periods of time. It was found in every case that the permeability values of cores prepared

from a given mixture were practically the same before and after being exposed to the moist air within green-sand molds.

Moisture Absorbed by Dry-Sand Cores

The amount of moisture absorbed by cores from the air within the green-sand molds is very small. The increase in weight of cores bonded with raw linseed oil after remaining in a green-sand mold for 24 hours amounted to 0.13 per cent of the weight of the cores before placing in the mold. Cores bonded with pitch or rosin had a maximum gain of 0.18 per cent, while cores made with water-soluble binders absorbed less than 1 per cent by weight of water in a 24-hour period. The tendency is for the moisture absorbed to increase with the length of time during which dry-sand cores remain in green-sand molds.

Conclusions

1. The strengths of dry-sand cores are decreased when the cores are exposed to moist air. The extent of this deterioration in strength is dependent on the type of core binder used in making the cores and the length of time the cores remain in the moist atmosphere. The importance of storing all cores in dry places and of limiting the length of time during which dry-sand cores remain in green-sand molds is apparent from the results of this investigation.

2. The permeability or venting property of dry-sand cores is not changed on exposure to moist air for periods of time up to twenty-four hours.

3. The amount of moisture absorbed by dry-sand cores from closed, green-sand molds is relatively small.

Acknowledgment

This investigation on one of the characteristics of dry-sand cores is part of a research program including the study of core sands, binders and practice which is supported by certain foundry interests in Michigan and directed by the Engineering Research Department of the University of Michigan.

Discussion

Chairman B. D. Fuller: I am glad Mr. Campbell made the statement that molasses left with no strength at all did not mean you could not use molasses, because you need not be frightened about that. Molasses was found in my experience to be the best binder I could obtain for small cores, such as were used in the making of the little wattmeter, which goes on the wall of your office, which were made by the hundreds of thousands under my experience, and as I say, with the best success with the molasses binder, but, of course, it has to be kept where it will not get damp.

E. W. Smith: Did you give any consideration to the sand which you used as compared with the sand in the West or a sand in the East?

H. L. Campbell: Yes.

E. W. Smith: In the East sands are found which are salty. In the Middle West we do not have them. I think Mr. Campbell's real intention is to bring out where and why cores weaken from the binders used, due to the tendency of something in there to absorb moisture. I think he has overlooked one fact, that there may be something in that sand which absorbs that moisture more readily than with other sand, and by taking that question up you may find in their proper proportions any core binder may be used. It is using it in excess that is wrong in any binding material, because it creates more gases and it is waste. But all binders used in their own particular proper proportion, all binders used rightly make perfect cores, and it may depend on some other element affecting all of those binders in the various proportions.

H. M. Lane: One more question I'd like to ask, Mr. Campbell, in that pitch binder, did you use the standard pitch binder obtained on the market or did you grind your own pitch?

H. L. Campbell: The pitch binder which was used in this investigation was obtained from the original source of pitch binders, and was pure pitch powdered to pass a 200 mesh screen in fineness. This pure pitch was sold not as a commercial pitch binder, but as pure commercial pitch.

H. M. Lane: I asked that question for this reason. Some years ago I was called to a foundry in tremendous hurry, on account of the fact the automobile foundry making a particular type of cylinder, in which they were using pitch binders had suddenly jumped from a loss of 4 or 5 per cent to a loss of 80 per cent of cylinder blocks. The trouble turned out to be that the pitch which they were getting was a commercial pitch, but had been mixed—in the first place they had gotten a pitch that contained too much ash, and they had put the usual percentage of dextrin in it, so they had gotten an off balance there.

On our pitch tests we found we had to bake them far enough to expel certain material and reduce the strength of the pitch core to a certain point in order to get it to hold up in the moisture test.

H. L. CAMPBELL: As to the point raised by Mr. Smith regarding the sand used in this investigation, it is stated in this paper that we used 60 to 70 mesh Ottawa sand, the sand that has just been adopted as the A.F.A. tentative standard sand for core testing work. In order to compare the different characteristics of the different core binders, of course, it is necessary to dispense with various factors which might influence results. Consequently, it has been necessary to use a uniform sand in all of this comparative test work. I want to make it perfectly clear that it was not our intention in any sense to show up any of the binders unfairly. We simply used the best possible mixtures. You will find in the paper all the details as to the mixtures we used, the temperatures for baking and all other factors. The aim was to use the best possible conditions in the preparation of the test cores, and to determine definitely the characteristics as to this moisture absorbing property and the effects on dry bond strength. There is no intention to discourage any one in the use of any binder; simply to have you definitely informed as to the characteristics of these materials, so you will know more intelligently how to safeguard the practice in the foundry.

Apparently this point on the effects of moisture absorption on dry bond strength has never been emphasized to the extent that it should have been long ago, and defective castings have been produced in a great many foundries due to this cause. Many cases have come to our attention since making these studies where cores have dropped, where defects were produced because of changes in shape of cores, simply due to this moisture absorbing effect on the dry bond strength, causing the cores to become too weak to hold up in the mold. We wish to have it definitely understood that we have no prejudice at all against any of the commercial binder materials. We believe that it is to the advancetage of the entire industry to know this characteristic condition of the effect of moisture absorption on the properties of dry sand cores.

J. MURPHY: What application would these figures have to foundries on the coasts of the country? There is, I believe, more absorption of moisture along the coast, on account of the salinity in the sand used, and the air also along the coasts of the country. I have seen a core, small cores, collapse entirely in two hours. There is this difference in the practice between the coast and Middle West and that is that a great many cores that are used in molds have to be rodded on the coast, where they would not have to be rodded in here. So it seems to me another set of figures might be necessary for those foundries on the coast, where there is a degree of salinity in the air and using beach sands, where the salinity is sometimes quite high, and there is a moisture absorbing element.

W. B. PERRY: Is there any one that has tried to put the cores in an oven and keep them at the proper temperature, or use it in a general way to overcome the difficulty Mr. Campbell has mentioned? Probably Mr. Lane has worked up some kind of apparatus that he has used in his designs. I as wondering if that is a common practice, or if that could be an addition

to Mr. Campbell's paper in the way of keeping the cores at proper temperature.

H. M. LANE: I became interested in that question some years ago. I wondered how old a core had to be before it was no good. I had made some cores in some tests when glutrin first was put on the foundry market. I knew they were stored on top of a core oven. I went back there three and a half years afterwards. I found the cores I had made up there. I got them to put the same pattern in the sand. I made more cores that day. We poured 25 molds with the cores three and a half years old, and 25 cores with molds made that day, and they were all good. I found flour cores that had been in storage nine and a half years on top of the core ovens and used them. If they have been stored where the temperature was high enough so that there has been no tendency for condensation in the core they were good indefinitely.

H. L. CAMPBELL: As to the point of heating cores for long periods, some cores are very susceptible to deterioration in strength when the baking is continued. Drying oils are not affected in that way as much as other binders are. Drying oils may be heated for long periods at certain temperatures and not be changed in properties very much. Other binders are rapidly deteriorated in strength, when exposed for long periods to any reasonable baking temperature. Consequently, the method of trying to resist the moisture absorbing property of say water soluable binders by heating the cores a long time will defeat the purpose of the core. That is, it will decrease the strength of the core. The chief advantage to the industry from the information which has been collected on the property of moisture absorbing on dry bond strength is that cores must be kept dry. Keep the cores dry and you are safe. They will last indefinitely. Cores will last forever if kept at sufficiently dry temperatures. Those binders which are affected by bacterial action, of course, must be kept dry at temperatures at which bacteria will not grow spoiling the binder in the core. Otherwise the core is good indefinitely.

A very simple experiment any one can try in the foundry is to make up some cores—probably you have all done this—with water soluable binders and allow them to stand around in a room exposed to the dampness of the air in the room or air outside. If you use a molasses binder it serves as an excellent barometer or indication of moisture conditions in the air. Some days when the air is damp and the humidity is high the core will become very soft. The next day you go over and pick up that core, it has become hard again—soft or hard, depending on the weather conditions. The moisture is lost if the air is dry; the moisture is gained if the air is damp, and that process will repeat itself. The core is not deteriorated, however, just simply changed. No matter whether the foundry is located on the coast or inland, the same property, the same effect of moisture absorption on dry bond strength will take place. It is just the influence of the moisture on the bond in the core which changes this strength of the core.

G. OLSON: I agree with Mr. Campbell very much on most of his points, so I don't come up to answer him, but I wanted to answer Mr. Lane's remark about cores. We don't like to scare everybody out of their wits about the cores lying around for so long and being no good by picking up moisture. We know they want to get back to the practical again. We know in the foundry we are making cores that have to be left lying around for months. We can't keep on drying out the air in the core. We know we have our foundry conditions to contend with. Those are conditions we absolutely have to figure with, and on discussing these things we had occasion some year and a half ago to leave some cores seven months in the foundry; with some 12 inch gate wells to be made, we changed the design of the pattern slightly. We left the cores lying out in the foundry. They were left from the month of August to the latter part of March. That means they had the bad months of the fall, from August to December —the cores were lying out all that time, unprotected. We took the cores and put them right in the mold and started to make the molds. We did not find a scab on one single casting. Mr. Lane said you will find scabs, but we didn't. The cores were made from Michigan City sand, half oil and half cereal binder.

E. W. SMITH: Have you ascertained what element it is that absorbs the moisture in the molds or in the drying condition or anywhere else? It looks to me like some one element, which must be searched out and avoided, whether in the binder or in the material. Have you ascertained what element it is?

H. L. CAMPBELL: The data which have been obtained indicate that the water soluble binders are influenced to a greater extent, as far as decreasing strength on exposure to moist atmospheres than the other binders, than the dry oil binders. There is no separate component in any of the binders that I know of on which you can base this decrease in strength. Linseed oil is not waterproof. I just bring this case in so you will see the point about the characteristic of these materials. Varnish is not waterproof. You can prove that easily by varnishing a piece of wood and putting it under water for a while, and you will find it increases in weight quite rapidly. Linseed oil is not waterproof. Water gets into the oil in some way. I don't know whether I can explain the actual theory involved in the change in the property of linseed oil, but the results indicate very definitely that the dry bond strength is materially decreased when exposed to moist air. I cannot explain in the case of linseed oil just why that is. In the water soluable binders apparently the moisture absorbed puts the binder into a liquid state again and the binder is soft, just as the core was soft before it was baked.

E. W. SMITH: I don't think the thought I tried to convey has got to you yet. Can there be, through your research, continued as well as it has gone, can there be brought out the elements which exist in any material we

use, to avoid that absorption of moisture? Can we ascertain what the material or what the element is that causes it?

H. L. CAMPBELL: I am sure we would like to try to find the exact cause and pick out that particular component in the core binder which is so detrimental. But the materials are very different, a drying oil dries by oxidation, it hardens by oxidation, not evaporation; a water soluable binder hardens by evaporation, entirely a different process, the materials are so different I doubt at this moment whether there is one exact component or material which is the cause of this deterioration in dry bond strength.

A. S. WRIGHT: I would like to inquire whether or not this property of moisture absorbing is experienced in cores when blackened?

Chairman B. D. FULLER: This has brought out a good many interesting things. It just calls to mind a little thing that I think is worthy of mention. Walking out on the dump one spring, where we had dumped our refuse sand, at the Westinghouse Company at Cleveland, I picked up a butt of an oil sand core which had lain there on that dump all winter. That core was sound. It had been under all sorts of weather conditions. I believe I could have dried the skin off a little and used it. What did that teach me? I was not thinking about the moisture absorption. It taught me I was dumping money over that dump. I think if you walk out in your dump and find the solid oil core dumps you will awaken to the fact that proper oil cores should come out with a very little rapping, mostly by itself. You can save some money. An oil sand core lying out there all winter, yet it was firm in shape.

H. L. CAMPBELL: A question was asked regarding experiments on cores which have been coated. Up to the present time we have made no experiments on coated cores. Our investigation has been just on cores which have been baked, without coatings. However, the coatings which are put on cores generally are not impervious to moisture. They don't resist moisture. Moisture passes through the coating. If you use a coating containing the same water soluable binders you use in the sand, they will absorb moisture just as the binder in the core will absorb moisture, and in that way transfer the moisture in the coating to the binder in the core. So I would predict offhand that the coating on cores would have very little effect on the properties produced when cores are exposed to moist atmospheres in green sand molds.

G. OLSON: Regarding the coating of cores, I have found that a coat of blacking and whatever liquid we use will not throw off moisture after it once has been saturated. It will retain moisture a good deal longer.

Routine Sand Control in the Pipe Foundry

By M. Kuniansky,* Lynchburg, Va.

For the past two and a half years our laboratory has been performing routine sand control work with a fair degree of success. Our losses in the various departments have been lowered and some of this reduction in losses can be rightly attributed to sand control. We have endeavored to keep our sand within certain limits for permeability, moisture, green strength and dry strength, for we feel that it is just as important to control the sand as it is to keep the iron mixture within certain limits.

It was the idea of the writer that the sand used for ramming the molds for the same size of pipe would be approximately the same in the various shops, but the testing of the sand used in ramming the mold for a 6 inch pipe from fifteen different shops varied enough to merit a study for the reasons for this variation.

In Table 1 are tabulated the results of tests of sands from the various shops. It is evident that all four of the factors, permeability, green strength, dry strength, and moisture, varied more than was anticipated.

Different Methods of Ramming Require Different Moisture Contents

The Lynchburg sand with 15 per cent moisture looked very high to us, so we started to lower it. By the time we reached 11 per cent we were in trouble. We found that jolt ramming of the type we used required a wet sand. In jolting a sixteen foot mold vertically the sand toward the top of the mold suffered from aeration when the moisture dropped to 12 per cent. The result was a weak mold at a point about two feet below the bell. Upon pouring, the iron washed this portion badly. On the other hand, with pneumatic ramming, such as is used with sand number one, a low moisture is required. As the moisture goes up on this type of ramming the speed of ramming is cut down

*Chief Chemist, Lynchburg Foundry Co.

and when the moisture is 12 per cent, the speed of ramming is cut almost in half.

Dry and Green Strengths

Strengths, both green and dry, are run on Dietert's shear testing machine, using the permeability specimen for this test. In glancing over Table 1, it is noted that there are several sands that illustrate the importance of controlling both green and dry sand strength. Sand No. 1 and sand No. 11 are both used in the centrifugal process for making pipe. In this process the sand problem is an important factor in the success of the plant. Sand No. 11 is used in a shop where the 16 foot molds are rammed by jolting. Sand No. 1 is used in a shop where the molds are rammed pneumatically. I have picked these two sands because they show the importance of sand control better than any other sands in the industry. Sand No. 11 has 3.1 per cent more moisture than No. 1. The reason for this difference is in the method used for ramming.

Table 1

Sample No.	Permeability	Green Strength	Dry Strength	Moisture Per Cent	Plant
1	313	.7	7.8	6.9	Mono-Cast
2	275	.8	8.8	7.6	Acipco
3	193	.9	8.6	12.4	Acipco
4	119	.55	3.2	10.5	Scotdale
5	358	.75	8.0	10.2	Bessemer
6	300	.7	8.6	13.2	National
7	185	.6	4.0	13.2	Radford
8	380	.5	12.2	14.9	Lynchburg
9	198	.85	2.8	9.8	Clow
10	67	.82	2.4	9.6	R. D. Wood
11	151	.73	11.4	10.0	Sand Spun
12	99	1.0	5.4	13.2	Chattanooga
13	112	1.35	7.8	15.7	Addyston
14	173	.60	1.8	11.9	Burlington
15	156	1.5	9.8	7.4	Clow

The shaking-out process is different at the two plants. In the mono-cast shop the sand is cut out of the flask and in the sand spun shop it is jolted out. If the sand bakes too hard from the skin drying before casting and from the pouring operation, it will be almost impossible to cut the sand from the mold in commercially practicable time. The jolt shaking-out process is not handicapped as badly by this. The sand must be sufficiently strong in the green state to withstand the ordinary handling operations previous to pouring and must dry sufficiently hard to with-

stand the flow of the metal. A sand low in dry strength washes badly during the casting operation.

In the old style of making pipe, it is necessary to have sufficient green strength to permit the rough handling of the rammed mold from the ramming station to the drying station. The dry strength must be sufficiently great to permit the rough core setting operation to take place without raking of the mold, although it is not always true that the resistance of the mold to raking by the setting of the core is greater with higher dry sand strength. Sand No. 14 in the dry was the weakest ever tested by the writer, yet we saw some of the pipe made from this sand and it looked very good. If the sand is too strong in the dry there is a tendency for the heads of the pipe to drop off. We have had as many as fifteen heads to drop off where the sand was too strong. Where a sand runner is used and pipe are cast bell up, the runner should be strong in the dry. Where the head core is nailed down by nails being placed into the sand runner, the head core will rise if the runner sand is too weak.

Permeability

Permeability plays an important part in the drying operation. We believe it requires less fuel to dry a mold of permeability 350 and moisture 15.0 per cent than it does to dry one of permeability 70 and moisture 9 per cent. When permeability of head core sand is high, we have less trouble from blow holes in the sockets. Oil sand head cores have been used at our Lynchburg plant for the past month with almost absolute freedom from blow holes in the sockets due largely to the higher permeability of the rammed head core. It is almost impossible to ram the head cores too hard when using oil sand.

Test Methods

Now just a word about the tests. The permeability is run according to the A. F. A. method, though the writer believes the use of one orifice is better than using two. It is very difficult to obtain check determinations on the two orifices on sand No. 8 and sand No. 10. The Dietert shear test machine is an improvement over the compression machine formerly put out by Dietert.

The use of the permeability specimen for the strength test saves time and also gives a truer relationship between permeability and strength.

The moisture test as outlined by Dietert will not give reliable results on most of the pipe shop sand given in Table 1. It is almost impossible to check these readings for moisture by actual weighing. On sands like No. 1 and No. 11, and on our sand in the fitting foundry, where we use a sandslinger, moistures can be checked within .3 of one per cent.

In the A. F. A. transactions, I see curves giving the characteristics of a molding sand through the entire range of workable moistures. In Table 2A are the results obtained on our sandslinger sand as used in the foundry. In Table 2B are the results obtained by drying the sand at 105 degrees Cent. and retempering to the indicated moistures. Tables 3A and 3B give the same results on our pipe shop ramming sand. The samples are all taken at one time and carefully mixed. Half the sand is used for the determinations in Tables 2A and 3A and the other half in each case is dried and used for the results in Tables 2B and 3B.

Table 2A

Permeability	Green Strength	Dry Strength	Moisture Per Cent
62	1.8	28.6	8.9
62	2.2	21.4	8.8
67	2.1	20.6	8.7
62	1.8	15.8	8.8
55	1.9	21.4	8.8

Table 2B

Permeability	Green Strength	Dry Strength	Moisture Per Cent	Per Cent Moisture Checked by Weighing
23.4	1.2	5.8	6.0	
33.0	2.5	10.2	7.0	
42.0	3.15	14.0	8.0	
44.0	2.0	16.4	9.0	8.9
38.0	2.0	23.2	10.0	9.7

In Table 2A there is a variation from 55 to 62 in permeability. Green strength checks fairly close. Dry strength, however, is very erratic. In Table 2B the sand when reworked to 9.0 per cent moisture which when checked by loss in weight showed 8.9 per cent cannot be recognized as the same sand in Table 2A.

In Table 3A on the coarse pipe shop sand the results check fairly well. In Table 3B, however, the sand when reworked to 14 per cent and 15 per cent moisture aside from the higher green strength looks something like the sand in Table 3A. We cannot

Table 3A

Permeability	Green Strength	Dry Strength	Moisture Per Cent
275	.5	17.0	14.5
264	.5	19.0	14.3
243	.52	....	....
275	...	18.5	14.5
275	...	....	....

Table 3B

Permeability	Green Strength	Dry Strength	Moisture Per Cent
205	.85	11.0	11.0
198	.8	11.8	12.0
236	.7	17.6	13.0*
253	.8	18.4	14.0
219	.7	23.2	15.0

see and cannot explain why the same sand when dried at 105 degrees Cent. and reworked to its original moisture should not give the same results as were obtained before drying.

Summary

In conclusion we wish to emphasize that despite the variations obtained on sands used at different shops for making the same casting, that there are benefits to be derived from routine sand control. It merely resolves itself to finding the type of sand suited for your particular shop, fixing the limits within which to keep the moisture, permeability and strength and then keeping it as nearly the same from day to day as possible. The results obtained are at least a basis for an intelligent comparison from day to day.

Discussion

Chairman B. D. Fuller: In the number of tests which are shown in Table 1, fifteen in number, you will note the wide variation in content of the moisture content of the different sands. It is explained by saying they have to have different moisture content for different methods of ramming. That we know, but why in a practice of making pipe you should have such a wide variation in moisture content is a mystery to me.

M. KUNIANSKY: That is probably due to the fact that some of the shops don't go into sand control. They are probably not aware of it, but in the different types of ramming, pneumatic, jolts, they have to have the moisture content to suit that type of ramming, but lots of fellows don't know the moisture content and strength of their sand.

DR. H. RIES: On page 173 you speak of the moisture test as not giving reliable results. I just want to ask which moisture test you referred to.

Secondly, take, for instance, Table 2, you refer to the green strength and dry strength. Is that the shear strength or compression strength?

M. KUNIANSKY: It is the so-called "shear" strength.

H. RIES: The third point is where, in Table 2A as an example, you give the shear strength as 1.8. That represents, I presume, the best shear strength to give you good results with minimum losses, does it? I would also ask the further question, how much variation in either direction can you allow without getting into trouble? That is one point I have always been interested to find out in connection with foundry sand control. For instance, some foundrymen will tell you that they must have a certain shear strength, we will say, perhaps, of one pound, and if the shear strength dropped to .9 or goes up to 1.1, they say, "Look out for trouble," so I am anxious to know if you can tell us how much variation there you can allow.

M. KUNIANSKY: I think that is drawing the line just a little bit too fine.

H. RIES: Some of them do it.

M. KUNIANSKY: In the first place, the accuracy of the test is not such as to permit of drawing the line that close. I would say in our experience on sand around 2 pounds, three-tenths of a pound either way would not be very noticeable in the shop. The moisture test is the test proposed where you use the gauge on the permeability rammer. That gives fairly good results on the finer molding sands, but when you get on a sand like pipe shop sand, that is fairly rough, you are way off base, and you have to use a different gauge on each different sand. It depends on the fineness. For instance, a pipe foundry sand and a fitting foundry sand in our case could not be run on the same gauge.

H. RIES: Is it not adjustable for different texture sands?

M. KUNIANSKY: You have to adjust it according to what you have in the shop.

H. RIES: If you adjust it, it is all right, then?

M. KUNIANSKY: It is within .2 of a per cent.

R. F. HARRINGTON: Do you think the reason you do not require greater accuracy is because of the character of the work being done in contrast to the work that might be done in Mr. Dietert's plant on radiators, something of that sort?

M. KUNIANSKY: That I could not answer fully, because I have never done any of that type of work. With our work we unquestionably have more latitude.

R. F. HARRINGTON: In reference to the question of buckles or scabs in dry sand work, I would like to ask whether the author has found any relation between permeability and the tendency for a mold to buckle or scab?

M. KUNIANSKY: In our dry sand molded practice in the pipe shop we have very little buckling or scabbing, that comes in our body core. That oftentimes is due, of course, to a low permeability, but we have no way of testing our body core mixtures, due to the fact that it is put on in a very fluid state and I have not been able to get at any way of testing it.

J. T. MACKENZIE: I wish to confirm Mr. Kuniansky's remarks about the moisture. As long as we stick to one sand we get moisture with that rammer within .2 or .3 per cent. Now, in the centrifugal process, where we keep the sand much more uniform than in the old shop, 1 per cent up or down is about the limit of moisture, and we find it entirely possible to keep that sand that way with the Dietert tester. The permeability on the centrifugal sand, as Mr. Kunanisky quote it, runs 313, but we have gotten it up to 450 and better. In fact, we run it up as high as 650, but as low as 300 we have trouble with that sand. I think the permeability spread is pretty large on low range pressure. The pressure difference of only .1 of a centimeter is quite a large variation in the permeability. I think that the figures were never intended to run up as high as 600 permeability. I don't believe you can possibly get results accurate within 50 points when you are up that high. Of course, down on the tighter sands you can get fairly accurate reports, but we have found unless you do actually screen the sand from time to time that these tests will not tell you the whole story. Sometimes the sand is porous from agglomerations of small particles. That gives us pretty good green strength and very poor dry strength. I don't believe that the dry sand test for permeability is as good as the green sand, because there is a tendency for the sand in drying to break away from the side of the container, and we find just an ordinary wash screen test, as given in the standard, is very, very valuable to carry along periodically. You don't have to run it regularly, but say once a week on each sand pile is well worth doing, because you can detect things that are not shown in these tests.

J. F. HARPER: What difference in permeability do you find necessary for your cores and for your outside mold in your pipe?

M. KUNIANSKY: We have not made an attempt to determine the permeability on our body core. As I explained to you, we have not been able to get that on account of the fact the body core mixture as applied usually carries around 25 per cent water. Possibly Mr. MacKenzie will be able to get permeability on the body core.

J. T. MACKENZIE: No, sir, we have been hunting some way of doing that a long time. We can't get at it.

M. KUNIANSKY: If you try to dry that mixture there is so much water in it that the evolution of the steam just makes that cake and the core that you get as a result is very porous and absolutely worthless for

strength or permeability tests. Mr. Sager suggested a jolting test, but that would not be a guide to our practice at all.

R. F. HARRINGTON: I understood the author to say that in pipe work they require increased moisture content in order to make the ramming effective, while as a matter of fact in green sand work in castings to a depth of 18 inches to 2 feet we find that too much moisture is a factor that works against jolting, and that the dryer the sand is up to a certain point the more effective the jolting. Therefore, the number of jolts in the machine can be cut down. I may have misunderstood the author.

M. KUNIANSKY: Ramming a mold 16 feet deep and one 18 inches deep are two horses of a different color altogether. We find in ramming on our jolt machine that we can't go above say 8 per cent moisture or 9 per cent, possibly, but you could not ram your molds for pipes 16 feet long that way. You would never get that at all.

CHAIRMAN B. D. FULLER: That question was one that interested me. From practical experience in ramming dry sand molds, possibly lots of you have had the same experience, you get your moisture way too high. If you have too high a moisture content your sand will sort of work one way or another. What I am thinking of is an experience in ramming locomotive cylinders in dry sand molds. If the moisture content in that dry sand mixture is too high, not only it will not ram properly, but after it is baked very often you find the breast of your mold cracked open. That is what made me ask in the first place about the high moisture content in the pipe work. It is rather surprising to me.

H. W. DIETERT: I really believe that the subject discussed is moisture and bond. I find that if you work your sand low in strength, low in bond, you can use very high moisture without any detrimental effects, but the bond must be low. If your water content is high then you get a high dry sand strength, which is very desirable in certain cases, in certain classes of work. That does not mean everybody wants to work weak sand, and on a heavy side, but it does offer wonderful opportunities. More castings are lost from excessive bond than from excessive water. It is the clay bond in there that is doing all the damage; if there is too much clay, too much bonding material, that films over and makes a tight surface, a ventless surface, and the gases are produced in the mold and not kicked off.

A. C. JONES: I'd like to ask in the sand No. 1 and No. 6, what is the variation in the average grain size? That is, in Table No. 1 I notice the moisture content of one is 6.9 and the other is 13.2. It is interesting to note in comparing the different moisture there, what is the different grain size?

M. KUNIANSKY: Mr. MacKenzie is in a better position to answer that. Sand No. 1 is used with a foot rammer, a pneumatic rammer. Sand No. 6 is used at the National shop, where the jolt rammer is used. You could not reverse those. You don't run sand No. 6 at MacKenzie's or No.

1 at the National. I say the grain size of sand No. 6 is much larger than sand No. 1. Is that right, Mr. MacKenzie?

J. T. MacKenzie: Sand No. 1 would be more uniform in grain than No. 6, but I don't know that the fineness in No. 1 would be appreciably different. The sand No. 6 would probably have a good deal of blacking in it which makes it run fine, but it is not sand; it is just blacking. That pipe shop sand builds up to 6 per cent carbon just from blacking, which means on an 85 per cent basis you have about 7 per cent blacking in the sand. One of the problems we have to contend with is in the first place if blacking dusts out of the sand we have got to contend with it, and if it doesn't we are worse off than we were before.

H. W. Dietert: I would like to ask Mr. Kuniansky whether the sands in Table 1 that show high moistures—there are certain sands there, some of them between 10 and 12, there is another group between 6.9 to 7.4—can those be classified in certain types of ramming, say a sand slinger and jolt or hand ramming jolt?

M. Kuniansky: There is not a sand in this series that is used in a sand slinger, but they can be classed as to pneumatic ramming and jolt ramming or the screw type ramming used by the U. S. Company. They all have to have moisture to suit that particular type of ramming to get the speed.

H. W. Dietert: The high moisture sands are the jolt and the low the pneumatic?

M. Kuniansky: Yes.

Report of Sub-Committee on Tests of Foundry Sand

To the Members of the American Foundrymen's Association:

The time which has elapsed since the last convention has been comparatively short, in fact, so much so that the committee has hardly had time to complete several of the investigations which it has initiated, but in spite of lack of time it is able to report progress, and even some results.

Contrary to what some might expect, the work of the committee instead of growing less, seems rather to increase. This is due first to the attacking of new problems connected with the testing of molding sands, and second to a necessary consideration of suggested improvements or changes in the methods already recommended.

The committee has always taken the attitude that it is unwise to make any recommendation without thorough investigation, and this has necessitated much work on the part of different members of the committee. The Chairman takes pleasure in acknowledging herewith the hearty cooperation and support which he has received from his colleagues.

With the growth of the sub-committee's work, it has also been found necessary to assign the investigation of special problems to sub-sub-committees of the sub-committee on tests.

Brief reference will first be made to work of these sub-committees.

Sub-Committee on Core Testing. This involves two important problems: (1) The selection of a standard sand to use in a core mixture for testing binders, and (2) the methods to be used for testing core mixtures.

With regard to the first, it may be said that the committee feels that a sand which passes entirely through a 60 mesh sieve, and is all held on the 70 mesh, would be the most desirable one to use. After conference with producers, it has been found impossible to get an ideal sand like this, and so the nearest to it is

tentatively recommended. This is an Ottawa sand, which shows the following grain composition:

Through	40 mesh	All
On	50 mesh	.5
On	60 mesh	4.5
On	70 mesh	90.0
On	80 mesh	4.5
On	100 mesh	.5
		100.0

With reference to the second part, attention is called to the fact that a premilinary report on the testing of core mixtures was given at the Detroit convention in October, 1926. At that time the tensile strength test was tentatively recommended for baked cores. Since then it has been found that quite a few persons are using a transverse test, and some a shear test, so the relative merits of the three are now being given careful consideration by the committee in order to determine whether one gives better results than the others, or whether all three may be regarded as satisfactory.

The sub-committee also has under investigation the determination of the best method for measuring the permeability of baked cores.

Sub-Committee on Testing Permeability of Molds. It has been pointed out that by attaching a tube to the A. F. A. permeability apparatus it can be used in the foundry to test the permeability of the sand in the molds. The shape and area of the tip fastened to the end of the tube, and which is pressed against the sand, appears to exert some influence, and so the best type to use is being investigated.

Sub-Committee on Shear Test. The main committee has already made recommendations regarding the method of making several strength tests, such as the bar, compression and tensile tests. More recently a shear test has been proposed, and another sub-committee has this under consideration, in order to determine if possible what relation it may show to the strength tests previously recommended, and also whether it possesses any marked advantage over them, or whether it can be regarded as co-equal with them in value.

Other Problems Under Consideration

Refractoriness Test. The determination of the refractoriness is still being investigated. C. M. Saeger of the Bureau of Standards and C. A. Hansen of the General Electric Company have been cooperating on this problem, and while both have carried on extensive tests, the results are not yet ready for submission to the association.

Moisture Test. A rapid accurate method of making moisture determinations on new sands, and also on the foundry floor, is still being sought. The alcohol-water method reported by the chairman at the Buffalo meeting of the sub-committee has since been tried with denatured alcohol and found not to be sufficiently accurate for our purposes. The sub-committee on tests has also been investigating other possible methods. Several methods, suitable for foundry control laboratory tests are now in use and giving satisfaction.

Sieve Test. There is nothing further to report on the sieve test, except that a new type of sifting machine has been submitted for consideration, and a number of tests have been made to determine to what extent the conditions under which the sieve test is carried out affect the results.

Tensile Tests. The sub-committee on tests has recommended that the tensile strength be expressed in ounces per square inch instead of pounds. This permits the use of large figures.

Permeability Test. Several interesting lesser problems have been presented as follows:

The suggestion has been made that a supply of what might be called a standard sand be kept on hand, so that in case of a difference of opinion arising between producer and consumer regarding the permeability of a sand, samples of the standard material could be obtained to test the permeability apparatus of both parties.

A canvass of the sub-committee on the desirability of preparing a standard sand, indicated a diversity of opinion, but it appears to be the view of a number that it is so easy to check the A. F. A. permeability apparatus, and determine whether it

is correct, that other means are unnecessary. There also appear to be difficulties in the way of maintaining a standard sand.

There seems, no doubt, that if two pieces of permeability apparatus are in a proper state of calibration, that differences which they show must be due to other causes than the apparatus.

It may be of interest to state that the Chairman and H. W. Dietert checked this point recently, using two permeability apparatus, cylinders and rammers. In the different runs, the several parts of the outfit were interchanged, and there was practically no difference in the results.

If the machine is kept in order, and the orifices clean, little trouble should be experienced.

The next question which has been raised is the nature of the support on which the rammer rests in preparing the permeability test piece.

It seems obvious that the rammer should stand on a firm and not a springy table, but in view of the fact that certain opinions had been expressed as to the great difference which might be caused by a difference in the solidity of the support, members of the committee were asked to make some tests to settle the matter. The results obtained are sufficiently interesting to be put on record and are shown in Tables 1 and 2.

Table 1

TESTS TO DETERMINE EFFECT OF SUPPORT ON PERMEABILITY

Tests Made at Ithaca

Mulled Sand	Run by H. W. Dietert: Perm. No.	Shear Test	Dietert Moisture Indicator Reading	Run by T. C. Adams: Perm. No.	Shear Test	Dietert Moisture Indicator Reading
Rammer on slate cover bench, not over leg of table	34	1.4	11.6	34	1.87	10.3
Rammer on same, over table leg	34	1.7	10.7	33	1.74	11.3
Rammer on concrete	31	1.3	10.2	36	1.68	10.3
Rammer on light wooden table top, not over leg; table very springy	34	1.62	8.2	40	1.48	10.2

Tests by A. A. Grubb

Light Table	Light Table	Heavy Table	Concrete Floor
26.7	26.0	24.2	22.9
24.7	26.4	24.2	22.4
25.0	26.0	24.2	23.9
25.5	....	....	....
25.5 Avg.	26.1 Avg.	24.2 Avg.	23.1 Avg.

Evidently there is as much as ten or twelve per cent difference, depending on how firm a support the rammer is rested upon.

Table 2

TESTS TO DETERMINE EFFECT OF SUPPORT ON PERMEABILITY

Tests by A. C. Jones

Base	Number of Specimens	Permeability
Concrete	3	170
Heavy wooden table (4 inches to the side of stout leg)	5	176
Alberene stone top	3	180
Light wooden top (the center of a ¾-inch board top about 16 inches from supports)	3	185

Tests made by C. M. Saeger

		Permeability	Compressive Strength
Light Table Top:			
A	1	23.01	2.8
	2	23.46	2.8
	3	23.66	2.8
	Average	23.37	2.8
Heavy Work Bench:			
B	1	24.11	2.7
	2	24.41	2.5
	3	22.58	2.7
	Average	23.70	2.65
Cement Floor:			
C	1	20.54	3.2
	2	21.29	3.5
	3	21.03	3.3
	Average	20.95	3.3
Steel Anvil:			
D	1	22.89	3.0
	2	22.58	3.0
	3	22.79	3.0
	Average	22.75	3.0

	Permeability	Compressive Strength
A	23.37	2.8
B	23.70	2.65
C	20.95	3.3
D	22.75	3.0
Average	22.71	2.93

Tests by W. M. Saunders	Permeability		
Rammer placed in the center of light wooden table	151	156	146
On a heavy wooden bench	138	142	142
On a bench having a post running from beneath the rammer to the concrete floor	138	134	138
On a slate table	128	128	134
On a concrete block	128	128	134

Tests by H. B. Hanley	Average Permeability
Poorly supported foundation, apparatus not firm and secure	28
Rammer on firm heavy bench, top of wood	27
Concrete foundation	27

Table 2
(Continued)

TESTS TO DETERMINE EFFECT OF SUPPORT ON PERMEABILITY

Tests Made at Hunt-Spiller Co.

Foundation Used	Permeability Core 1	Core 2	Core 3	Core 4	Average
Light wooden table	53	54	53	..	53
Heavy wooden bench	50	49	48	..	49
Concrete surface	46	44	39	..	43
Center of lightly constructed bench	54	52	52	..	53
Two-inch iron slab	44	46	46	..	46
Heavy wooden bench	50	52	51	..	51

Note—Heavy wooden bench repeated to check temper of sand.

Mr. Jones comments:

"You will note that there is some difference which might not be considered very serious but is sufficient to suggest a standard support or base for ramming, bearing in mind the desire to obtain the maximum rigidity or stability."

Mr. Saeger, regarding his test results, says:

"The results of my tests do not indicate that the different bases effect the permeability values.

"Our rammer device differs from the one shown in the A. F. A. pamphlet, in that the base is made of iron, instead of wood. The dimensions are 11" x 6" x 1" and weighs 19¼ lbs., the bottom pedestal weighs 2¼ lbs., or a total weight of 21½ lbs. This heavy base in itself acting as an anvil may account for the good results obtained."

From the results made at the Hunt-Spiller Co. it is evident that there is some variation in permeability due to the firmness of the surface on which the rammer is placed, viz.:

	Average Permeability
Light wooden table	53
Heavy wooden bench	50
Two-inch iron slab	46
Concrete surface	43

The iron and concrete surfaces giving readings 13 and 19 per cent respectively below the light wooden table and 8 and 14 per cent respective below the heavy wooden bench.

It may be also of interest to present some figures on another question which has been raised, viz., whether there would be much difference in permeability, depending on whether the sand

was rammed to the upper, middle or lower line on the gauge at top of rammer.

Three sets of figures have been sent in and are shown in Table 4.

Table 4

EFFECT OF RAMMING PERMEABILITY SPECIMEN TO UPPER, MIDDLE AND LOWER LIMITS OF SPECIMEN LENGTH

A. C. Jones	Permeability
Upper line, average of three tests	212
Middle line, average of three tests	210
Lower line, average of three tests	207

W. M. Saunders	Permeability	
Upper line	128	134
Middle line	138	138
Lower mark	134	128

Hunt-Spiller Co.	Permeability				
Length of Core	Core 1	Core 2	Core 3	Core 4	Average
Variation limit—2 inches plus	49	48	46	46	47.0
Exact 2-inch core	50	48	53	50	50.0
Variation limit—2 inches minus	47	46	51	50	48.5

	Permeability				
Length of Core	Core 1	Core 2	Core 3	Core 4	Average
2 inches	102	105	102	...	103
2 inches plus	102	102	108	108	105
2 inches minus	108	105	108	...	107

	Permeability				
Length of Core	Core 1	Core 2	Core 3	Core 4	Average
2 inches	146	151	151	144	148
2 inches plus	148	142	144	151	146
2 inches minus	142	142	146	...	143

A fourth set of tests made by C. M. Saeger, Jr., and the Chairman, showed no more variation than might be expected in a triplicate test of the same sand sample.

Another suggestion has been made that in view of the fact that for any given manometer pressure the permeability for the large orifice is approximately 10 times that for the small one, the opening of the latter should be adjusted so as to make it exactly so. Since it is not possible to make the ratio an exact one for all pressures, the committee has almost unanimously voted against the change.

Mr. Grubb has suggested that a No. 11 rubber stopper with a metal or glass insert in which there is an orifice, would serve as a standard permeability test piece. It can be readily calibrated and its values will remain constant. It has this disadvantage: its permeability is different for different pressures, so it would be

necessary to supply four values with each test piece; standard method, weight off; standard method, weight on; small orifice, and large orifice. This is due to the fact that for very fine capillaries, such as found in a sand specimen, the rate of flow varies very nearly directly as pressure, while for larger tubes this relation does not hold. Its values, as determined on our machine, are as follows:

Standard method,	5 cm.	pressure,	perm. is	25.26
Standard method,	10 cm.	pressure,	perm. is	19.80
Small orifice,	2.64 cm.	pressure,	perm. is	35.20
Large orifice,	8.82 cm.	pressure,	perm. is	21.25

It may be of interest to call attention to a new type of permeability machine exhibited at this meeting and designed by T. C. Adams.

The apparatus, instead of using an orifice, employs a sand cartridge.

Compression Apparatus. The desirability of a cheap compression apparatus for testing baked cores has been voiced by the committee, and attention may be called to the fact that one with a capacity of 500 lbs. is an exhibition at the convention.

Directions for Making Tests. Since the first pramphlet on testing molding sands was issued in June, 1924, a number of important improvements have been made in the methods of testing, and additional ones have been recommended, so that it has seemed desirable to issue a new edition. Mr. Kennedy is now engaged in the preparation of this.

Respectively submitted,

H. RIES, *Chairman,*

Sub-Committee on Tests.

Report of Sub-Committee on Grading

To the Members of the American Foundrymen's Association:

The most important development in the grading of foundry sands since last convention was the publication by the American Foundrymen's Association of a circular in poster form describing in detail the system for grading or classifying sands according to grain fineness and clay content. Credit is due the technical secretary of the Association for the clarity and splendid form in which this material was presented.

These grading classifications are reproduced on page 195 of this volume.

It is our earnest desire that foundrymen and producers of sand apply these classifications to their sands, give the system a trial and bring their comments to the committee. Following are some comments which we have received:

One producer reports that he has a pit which produces sand ranging in grain fineness from 95 to 104, clay 11 to 15 per cent. This sand may be either a No. 3-E or a No. 4-E sand. Designating it as such implies that the sand may have a grain fineness anywhere between 70 and 140, while as a matter of fact it runs very uniform. How should he designate such a sand? The sub-committee suggested that he use the figures 3-4 to represent the grain size and that such designation be taken to mean a coarse No. 3 or a fine No. 4 sand.

Another producer and a purchasing agent have suggested that the zone limits on grain fineness are too wide. Sands may differ too widely in grain fineness and still be in the same grain class. It was suggested that for the present the terms "fine" and "coarse" be prefixed to indicate whether the sand lies in the upper or lower part of the zone. If such criticism is found to be general, the sub-committee will gladly alter the zone limits to meet the needs of the users of the system.

In general we have not had sufficient criticism—pro or con—to warrant any changes in the system.

It was pointed out in our previous report that classification as to grain fineness and clay content does not completely describe

a sand. In other words, two sands of the same grain fineness and clay content may differ greatly in chemical analysis, grain shape, grain distribution, clay distribution and quality of clay, and so behave differently in use. Further classification is therefore desirable.

At a meeting of the sub-committee held in Buffalo, N. Y., on February 5, 1927, it was the feeling of those present that the following characteristics should be given attention with view to further classification of sands:

(1) Grain Distribution.
(2) Grain Shape.
(3) Quality of clay (Colloid Content).

The major part of the problem really consists in measuring and expressing these characteristics in numerical or other standard terms. A brief discussion of these characteristics follows:

Grain Distribution

Sand of uniform grain size has characteristics quite different from a sand of the same average grain fineness but of a wide range of grain sizes. The latter packs more densely, the small grains tend to fill the space between the larger ones and lower permeability and higher green bond strength results. For high permeability a uniform grain size may be desirable while for high green bond and smooth mold or core surface, a rather wide grain distribution may be desirable. At present we have no standard method for expressing grain distribution numerically.

The W. S. Tyler Co., of Cleveland, Ohio, describes in their catalog a system for determining a "Uniformity Coefficient," which is used in connection with filtration problems. Using the screen analysis as a basis of calculation, the dimension of the screen opening which will pass 60 per cent of the sample is divided by the dimension of the screen opening that will pass 10 per cent of the sample. The nearer unity this coefficient is, the more uniform is the grain size.

J. W. Bolton has suggested the following system for obtaining a distribution factor: To the percent of sand in that screen interval in which the grain fineness figure lies, add the percent-

ages in the next finer and next coarser intervals. The sum is taken as an index of the grain distribution; the higher this figure the more uniform is the grain.

W. C. Hamilton outlines another method for handling grain distribution. The grain fineness is calculated as in the present A. F. A. tentative method. The mesh number of that screen which would pass half of the grain and retain half is determined. This latter is the figure which C. A. Hansen[1] represented with his "median index number." The A. F. A. grain fineness figure weights the fine material, the median index weights neither fine nor coarse material, so by taking both figures an idea of the grain distribution as well as the average fineness is obtained.

This information, however, is not readily apparent. Furthermore, there seems to be no simple method for expressing the grain distribution by one figure. The principle back of the method is good, however, because it takes account of grain distribution over the entire range of screens. It suggests a modification which does yield a single figure and which does express the grain distribution over the entire range of screens.

The method which Dr. H. Ries[2] formerly used for calculating average grain size, like the present A. F. A. method, yielded a number which represented the number of mesh per inch of the screen which would pass the average grain, but unlike the A. F. A. method, it weighted the coarse material; the A. F. A. method weights the fine material[3]. If, now, the same mesh numbers are used in both methods (taking the reciprocals of the mesh numbers as the multipliers in Ries' method), then the two methods will yield identical results, but only when the grain is of a uniform size, that is, all is caught on one screen. The ratio between the two fineness figures is then unity. When material lies on more than one screen, the Ries method weights the coarse material and produces a figure lower than that produced by the A. F. A. method which weights the fine material. The ratio is now less than unity. This ratio figure is, then, a definite measure of grain distribution and takes into consideration all the grain on all the screens.

[1] Trans. A. F. A., Vol. XXXIV, 1926, p. 382.
[2] Mich. Geol. Survey, Annual Report, 1907, p. 50.
[3] See Trans. A. F. A., Vol. XXXIV, 1926, pp. 496-498.

Following is the method of calculation together with an example:

On	6	0 ×	3 =	0	0 × 1/3	=	.00
	12	0 ×	5 =	0	0 × 1/5	=	.00
	20	6 ×	10 =	60	6 × 1/10	=	.60
	40	12 ×	20 =	240	12 × 1/20	=	.60
	70	15 ×	40 =	600	15 × 1/40	=	.38
	100	30 ×	70 =	2100	30 × 1/70	=	.43
	140	15 ×	100 =	1500	15 × 1/100	=	.15
	200	10 ×	140 =	1400	10 × 1/140	=	.07
	270	2 ×	200 =	400	2 × 1/200	=	.01
	Pan	0 ×	300 =	0	0 × 1/300	=	.00
				90 / 6300			90 / 2.24

$$\text{Grain Fineness} = \frac{6300}{90} = 70.0 \qquad \text{Ave. Size } \frac{2.24}{90} = .0249''$$

$$\text{Grain Distribution} = \frac{40.1}{70.0} = .57 \qquad \text{Ave. mesh } \frac{1}{.0249} = 40.1$$

Following are four screen analyses, all of the same A. F. A. grain fineness but varying in grain distribution:

	(1)	(2)	(3)	(4)
On 6	..	..	..	..
12	..	..	..	..
20	..	..	..	6
40	..	..	6	12
70	..	5	10	15
100	90	80	60	30
140	..	5	9.5	15
200	..	..	4.5	10
270	..	..	..	2
Pan	..	..	..	..
Clay Substance	10	10	10	10
A. F. A. Grain Fineness	70	70	70	70
Ave. mesh (Ries)	70	68.4	58.8	40.1
Grain Distribution	1.00	.98	.84	.57

Grain Shape

This characteristic of foundry sands has had comparatively little attention so far as we are able to learn. Several investigators have reported finding marked differences in refractory qualities, permeability and bond strength due to shape of grains but there seems to have been but few quantitative measurements made. There is little doubt, however, but that grain shape is an important factor.

Apparently no attempts have been made to express grain shape numerically. Geologists and to a certain extent foundrymen use the terms *angular, sub-angular* and *round* to describe grain shape. There is the possibility that a sand which one observer

would term sub-angular might be classed by another as angular, and until some more definite means of defining the terms and measuring the grain shape are developed, such questions cannot be settled. It is possible, however, that these terms are sufficient for our purpose.

Quality of Clay

This characteristic needs further definition. Clays differ widely in bonding power, plasticity, durability and refractory qualities. Chemical composition is no doubt an important factor in determining these properties. Shape of particles may have effect. Probably the most important factor, however, is particle size.

The particles of clay range in size from about one-thousandth of an inch diameter down to almost a millionth of an inch. No. 6 mesh sand grains are of about 100 times the diameter of the smallest grains in the pan material. There is even wider variation in the size of particles that may compose clay, yet we group all these sizes together under the one name—clay substance.

The physical properties—cohesiveness, plasticity, etc., vary greatly with size of particles in the clay. Particles less than a hundred thousandth of an inch in diameter have properties so different from larger particles that they are known under a special name—colloids (from Greek *Kolla,* meaning glue). Such particles are capable of absorbing great quantities of water and when wet are very sticky. Pure colloidal matter once wet and then dried has strength comparable with that of portland cement. Some clays contain practically no colloidal material—the particles are practically all larger; other clays contain appreciable quantities of colloids, and bentonite contains as much as 75 or 80 per cent.

In order to classify sands with respect to the quality of clay, it is necessary to classify clays with respect to particle size. This involves methods of measuring and expressing the particle size. The Sub-Committee on Tests is giving this matter attention. Dye adsorption, water adsorption and sedimentation methods have been tried and seem to be of value. At the present time, data

obtained by such methods are meager and not well understood. When sufficient progress has been made to warrant the step, we hope to set up a system for classifying clays that will be of real value to foundrymen and sand producers.

Respectfully submitted,

A. A. GRUBB, *Chairman,*
Sub-Comm. on Grading.

Tentative Standard Grading Classifications for Foundry Sands

There has been a growing sentiment among sand producers and foundrymen that a uniform method of grading foundry sands would be of advantage to all concerned. While nearly every producer has for years graded his sands in one manner or another, the systems employed have differed so widely that there has been confusion when discussing grades of sands with different producers. With a view to remedying this difficulty and providing a standard system of grading sands, the Executive Committee of the Joint Committee on Molding Sand Research, late in 1924, created a Sub-Committee on Grading composed of representatives from the foundrymen and sand producer groups. This sub-committee considered the various systems in use, compiled and examined a great mass of data on sands under production, and, after two years of work and numerous committee meetings, presented a report at the 1926 Detroit meeting of the A. F. A. in which it recommended practical methods for grading or classifying foundry sands as regards their fineness and clay contents. These methods were approved by the Executive Committee of the J. M. S. R. C. and in December, 1926, were approved as tentative standards by the Board of Directors of the American Foundrymen's Association.

It is hoped that these methods of grading or classifying sands will be employed by foundrymen, sand producers and others throughout the country. It is recommended that foundrymen grade the sands they are using according to the system outlined and that the A. F. A. grade numbers be used wherever practical; also that sand producers and sales organizations grade their products according to the same system and offer them under their A. F. A. grade numbers. Inasmuch as the present classification covers grain fineness and clay content only, further descriptive terms should be added, such as producers' name, locality in which produced, trade name and other characteristics.

A graphic representation of the screen analysis is highly valuable in visualizing the grain distribution.

The grain fineness number, grain fineness classification and clay content classification are given below.

A. A. Grubb, *Chairman* W. C. Hamilton
E. M. Ayers H. B. Hanley
J. W. Bolton C. M. Nevin
J. A. Capp G. F. Pettinos
Sub-Committee on Grading

Grain Fineness Number

Definition

The *grain fineness number* of a sand is approximately the number of mesh per inch of that screen which would just pass the sample of sand if its grains were averaged in size. It is approximately proportional to the surface area per unit weight of a sand, exclusive of clay.

Method of Determination

Make the standard A. F. A. fineness test by removing the clay and screening the grain. Multiply the weights of percentages of sand on the various screens by the appropriate factors listed below. Add the products. Divide by the sum of the weights or percentages. The dividend is the A. F. A. *grain fineness number*. Below are listed the multipliers for the corresponding mesh numbers.

Multipliers

Multiply per cent remaining on No.	6	mesh by	3
Multiply per cent remaining on No.	12	mesh by	5
Multiply per cent remaining on No.	20	mesh by	10
Multiply per cent remaining on No.	40	mesh by	20
Multiply per cent remaining on No.	70	mesh by	40
Multiply per cent remaining on No.	100	mesh by	70
Multiply per cent remaining on No.	140	mesh by	100
Multiply per cent remaining on No.	200	mesh by	140
Multiply per cent remaining on No.	270	mesh by	200
Multiply per cent remaining on Pan		by	300

Grain Fineness Classification

Grain Class	*Grain Fineness Zone*
No. 1	200 to 300
No. 2	140 to but not including 200
No. 3	100 to but not including 140
No. 4	70 to but not including 100
No. 5	50 to but not including 70
No. 6	40 to but not including 50
No. 7	30 to but not including 40
No. 8	20 to but not including 30
No. 9	15 to but not including 20
No. 10	10 to but not including 15

A sand is in that grain class in which its grain fineness number falls accordingly to the above grain fineness zones.

Clay Content Classification

Clay Class	*Clay Content Zone*
A	0.0% to but not including 0.5%
B	0.5% to but not including 2.0%
C	2.0% to but not including 5.0%
D	5.0% to but not including 10.0%
E	10.0% to but not including 15.0%
F	15.0% to but not including 20.0%
G	20.0% to but not including 30.0%
H	30.0% to but not including 45.0%
I	45.0% to but not including 60.0%
J	60.0% to but not including 100.0%

A sand is in that clay content class in which its percentage of clay substance falls according to the above clay content zones.

Example Showing Calculations to Obtain the Grain Fineness Number, Grain Fineness Classification and Clay Content Classification

The fineness test data of Millville, N. J., coarse molding gravel as reported in the Transactions of the American Foundrymen's Association, Vol. 32, Part II, page 338, Lab. No. 501, is as given below:

8.10 per cent clay substance
0.64 per cent sand grains caught on No. 6 screen
28.78 per cent sand grains caught on No. 12 screen
20.98 per cent sand grains caught on No. 20 screen
16.16 per cent sand grains caught on No. 40 screen
20.38 per cent sand grain caught on No. 70 screen
3.06 per cent sand grains caught on No. 100 screen
0.60 per cent sand grains caught on No. 140 screen
0.20 per cent sand grains caught on No. 200 screen
0.28 per cent sand grains caught on No. 270 screen
0.60 per cent sand grains caught on Pan

The calculations made by following the directions for obtaining the grain fineness number are as shown below:

Mesh No.	Per Cent Sand Remaining on Screen	×	Multiplier	=	Product
On 6	.64	×	3	=	1.92
On 12	28.78	×	5	=	143.90
On 20	20.98	×	10	=	209.80
On 40	16.16	×	20	=	323.20
On 70	20.38	×	40	=	815.20
On 100	3.06	×	70	=	214.20
On 140	0.60	×	100	=	60.00
On 200	0.20	×	140	=	28.00
On 270	0.28	×	200	=	56.00
On Pan	0.60	×	300	=	180.00
	91.68 = Total Sum				2,032.22 = Total Product

The total product of 2,032.22 divided by the total sum of per cents remaining on each mesh which is 91.68 gives 22 or the *grain fineness number.*

$$\frac{2{,}032.22}{91.68} = 22 \text{ or } \textit{Grain Fineness Number}$$

With the *Grain Fineness Number* known, then by looking up the *Grain Fineness Classification* it is noted that a sand with a Grain Fineness Number from 20 up to 30 is in the No. 8 *Grain Class.* The sample having 8.10 per cent clay would fall in Class D *Clay Content Clasification.*

Therefore, so far as the two classifications are concerned, namely, Grain Fineness and Clay Content, the sample would be described as a *No. 8-D* Sand. Inasmuch as this description covers only grain fineness and clay content, the sand should be given more complete designation—as for instance *No. 8-D Millville, N. J.,* Sand.

Report of the Sub-Committee on Conservation and Reclamation

To the Members of the American Foundrymen's Association:

The Sub-Committee on Conservation and Reclamation had not met as a body since the Detroit Convention of 1926, until Monday of this week. The lines of effort as outlined at the Detroit Convention have gone forward, however, and this report will cover these activities.

The sub-committee appointed to study clay bonds under the direction of C. A. Hansen of the General Electric Company at Schenectady, has completed an enormous amount of work in an attempt to evaluate clays. This work has shown quite definitely that a viscosity test for clay offers considerable merit, and this line of effort is to go forward. There have been many problems confronting the committee selected to evaluate clays, and many of the present-day tests have failed to detect many of the physical characteristics.

It is hoped that the viscosity test may offer a better means of evaluating clays, although it is to be realized that the work must necessarily move slowly to insure the best final results.

There has been no experimental work immediately under the direction of the Sub-Sub-Committee on the Reclamation of Steel Molding Sand. The reason for this being that many steel foundries have been carrying out experiments on their own account far more extensive than could possibly be undertaken otherwise. Practically all have adopted the dry method.

This method, it is felt, will prove to be, in all except a few instances, more economical than the wet system, in which the sand would pass through some washing and drying process.

There are represented in the dry system two different ideas, (1) making use of screens to separate the fines from the sand body, together with the use of various types of dust arrestors to deposit the fines in a manner convenient for wasting. This type of installation seems to be used ordinarily in works that take the

castings to one or more locations where the sand and cores are shaken out. The other type takes all the sand to a separate reclaiming plant, where it is first prepared mechanically for the separation of the waste materials and usable product, the separation being accomplished by a pneumatic system.

Both types, it is reported, are proving highly successful, and each probably has its own application. It is clear from the information that comes to the committee that the system which provides a preliminary preparation before separation is producing a product that can be used without any limitation.

The committee reports, therefore, that steel molding sand reclamation is an accomplished fact, proven by a year or more of experience, and it is just a question of how far the steel foundry wishes to go. The equipment is available, and the systems have been worked out even to the extent of turning out a product, the qualities of which are as good as a sharp silica sand. By sharp silica sand is meant one that has no appreciable natural bond.

The committee has been advised that much of the equipment used in the steel molding sand reclamation was on exhibit at the Detroit Convention, and that since that date, further investigation has allowed for improved equipment.

Use of Clay Bond

The committee, in order to check the extent to which clay bond was being used, communicated with a large number of plants reclaiming sand. These were representative of a heavy tonnage, and the committee can, without fear of contradiction, state that clay bond today forms a very definite and large part in our sand conservation programs.

Respectfully submitted,

R. F. HARRINGTON, *Chairman,*
Sub-Committee on Conservation and Reclamation of Foundry Sands.

Discussion

J. F. Harper: I would like to ask Mr. Harrington what method they have found best to remove the so-called ash or the spent wastes, the very fine matter that is left in the clay. I am not speaking of organic ash but I am speaking of very fine colloid or clay that is left or split particles of ashy silica grains left in the sand, which tend to close up the sand and give you high permeability.

R. F. Harrington: I might answer that by stating that there was equipment at the Detroit convention that is being used in industry for that purpose, and that it involves the dry screening of the sand and the material below the 70 mesh, for example, is removed with its consequent removal of material of pan size, and in one particular test that I am especially familiar with, 13 per cent of material was removed under these conditions. In the other practice, namely, in the steel problem, the process has worked in the same direction and I am advised that they have definitely removed the fines, not in a sense that they are necessarily the clay but the ash, as Mr. Harper has mentioned, from the material. I am sorry that from our own experience we cannot report on that particular phase of the subject. I understand, however, that some 18,000 tons of supposedly unusable steel sand was made useful through this process, and that the use of that sand was eminently successful, and if Mr. Harper would care for further details I could submit them.

H. M. Lane: I might simply say something that was done a good many years ago. We cleaned over 2000 tons of waste foundry material of various classes and used it all. We made a considerable tonnage of castings in the gray iron and steel and some brass and bronze. The simplest method we found was to have a series of baffles in a flue, so that the sand fell about 4 inches, and then fell over successive baffles. Our original installation had 20 feet of those baffles. We soon found that was totally unnecessary. We could clean the sand sufficiently in 5 to 6 feet. We had a screen to take out rubbish, coarse stuff, and for convenience ours was put at the bottom. Higher up we had a bucket elevator going up, discharging at the top of the cleaner, and on the side we had an air chamber, on the opposite side a series of holes, so we could control the amount of air. We had an exhaust into the dust arrester. We tried cross screens and the cyclone type. We found for the majority of sands the cyclone type was all right, and that we were able to waste into a bin practically all the dust, and in the many tests made, with the exception of two sands, 13 to 14 per cent was all we ever took out as dust, or we had to take out. I have set that thing so as to take out everything under 60 mesh without any trouble at all, and I have set it to finer meshes, taking it out.

The castings that were made with this sand were interesting in one way, in that we did not lose a casting, and we ran between 100 and 200 tons of castings. We watched them very carefully, the pouring and everything. We made about 200 Ford cylinders, in which every core in the

casting and the mold itself was made from reclaimed sand, and the mold was made from reclaimed jacket sand from other cylinders, and then bonded with clay, and we did the same thing on the Studebaker cylinder and the same on the Cadillac, back at the time the Cadillac was cast in four separate sleeves to make up their cylinder.

R. F. HARRINGTON: I am very glad that Mr. Lane has brought to your attention this possibility in the direction of the cyclone separator, because I had failed to mention that, and I understand that is being used; it has come to the committee's attention that this cyclone process has been proving eminently successful, although the number of installations in that direction, I understand, is limited. But as Mr. Lane has indicated, the possibilities seem very definite in that direction.

H. L. MCKINNON: One steel foundry has come across my range of vision this year where they are using a modification of several of these methods. They are using a vibrating screen and the screen is placed over a storage bin, and they box under the screen in two directions, carefully. They put an exhaust fan on one side, drawing a current of air directly across under the screen in that manner, eliminating the fines in a very satisfactory manner. They did put up a cyclone to catch the dust from the fan but that they found to be unecessary. They just run the pipe down over the side of the building and they have a pipe in the bin that loads directly onto the cars, and they get rid of the dust in that manner.

Characteristics of Some Steel Molding and Core Sand Materials

By E. R. Young,* Detroit, Mich.

Introduction

Steel foundry facing sands, omitting the natural bonded Eastern sands, are ordinarily synthetic mixtures, with a nearly pure silica sand as a base. Accordingly, they correspond more closely to the core sand mixtures, made up from sharp sand used in iron and non-ferrous foundries than they do to the natural bonded molding sands. Therefore, a number of the generalizations made in foundry literature regarding molding sand do not apply to steel foundry conditions. This distinction is familiar to all steel foundrymen, but is not so clear to all the investigators of foundry sand and may be worth emphasizing for a moment in introducing this subject. For this same reason, i. e., that steel foundry molding and core sands are both synthetic mixtures, it is convenient to include both in a discussion of the ingredients of these mixtures.

In conducting experimental work seeking cleaner and easier cleaning castings, the writer has come to think that good quality steel foundry materials are pretty nearly adequate to the job and that what we need is a better application of them. He has also been impressed by the fact that the shop men know quite accurately how to produce a given result on a definite, difficult casting when studied as an individual problem and that the difficulties attributable to sand facing or cores are frequently the results of a general practice which may not be so well thought out or which may misapply the material to a specific job.

A Survey of Materials and Practice

In this paper the writer has attempted to present a survey of the common materials, their behavior described in shop terms,

*Research Engineer, The Detroit Steel Casting Co.

what we expect of them, and what we get from them, with the thought that it might present the basis for a common discussion of theories and observations and might lead to something worth while.

As stated, we are not all always consistent in the use of materials in making up facing sand and core mixtures, and probably we are not all sure of just what we expect of these materials and what we secure from them, so a tabulation of this nature even though incorrect as it is sure to be in some of its details, if corrected, discussed and amplified, should help to clarify our knowledge of the materials listed, and aid in a more logical and efficient use of them.

The data given in this paper are therefore not a report of research and of tests to determine new or unknown properties, but are tabulations of the known properties of some of the common materials used in making up the synthetic molding and core sand mixtures. Table 1 lists seven materials exclusive of silica sand, the relative green and dry bond of each, relative cost of each kind of bond, the nature of the material, as mineral, vegetable, volatile, combustible, etc., and the melting points of the solids when definite, temperature at which dry bond is destroyed, condition after baking or drying as to hardness, behavior under heat as to hardness, and nature or rapidity of collapse, tendency to absorb moisture, effect on refractoriness of the sand, effect on permeability of sand, effect on ease of removal of sand and casting surface resulting.

Because of the difference of opinion as to the best method of determining green and dry bond, and the necessity of standardizing all the factors involved there has been no attempt to give absolute values for these properties, but only to indicate their relative values.

Regarding the data on nature of materials, there has been no attempt to go deeply into the physical or chemical properties of the materials, but only to give a description of them in simple terms, as of mineral or vegetable origin, combustible or incombustible and the per cent which forms gas, per cent which forms ash, together with the significant melting points. This may seem merely the repetition of commonly known facts, but the object is to try to accurately describe from the shop viewpoint the actual

behavior of the materials in the preparation of molds and cores and the behavior when subjected to the action of molten metal in pouring. So this table lists only these simple characteristics and goes more into detail regarding the history of the material in the foundry.

To pass judgment on the behavior of materials and the results secured with them, it is necessary to designate as closely as possible the type and cause of defects attributed to materials, as erosion or cutting, fusion, penetration, spalling or burning down, etc.

If we can agree as to what occurs and why, we will be in a better position to correct difficulties. In talking with practical foundrymen—and they are in a position from years of observation to state what seems to occur in a mold—it is apparent that they do not all agree in their observations or have the same explanation for occurrences and that sometimes they reason from false assumptions regarding materials, so there is room for a careful recording of observations which will permit a correct statement of happenings.

For example, we talk of refractoriness and fusibility, but do we actually have any fusion of good materials or is a matter of penetration or erosion perhaps due to lack of baked bond? Why is it that when the sand has a fusion point well above the pouring temperature of the steel, the fire clay has a fusion point above the pouring temperature and the finished facing mix from these two materials also has the same high fusion point we still have sand "burning in"? Do we have actual local fusion or do we have erosion or cutting of the sand surface and penetration of the metal into the surface layer of the sand for that reason? If so, what is the relation of the cutting to the amount and durability of the dry sand bond or baked strength of the mold or core, and what is the relation to the fineness or closeness of the sand surface?

Some of these questions are discussed briefly following the explanatory remarks regarding the data of Table 1.

Table 1

CHARACTERISTICS OF MATERIALS

Material	Nature	Melting Point, Degrees Fahr.	Green Bond		Dry Bond			Effect on Refractoriness of Sand	Effect on Permeability of Sand	Condition After Drying	Tendency to Absorb Moisture	Behavior of Bond at High Temp.		Ease of Removal of Sand	Casting Surface Resulting
			Amt.*	Cost*	Amt.†	Cost†	Temp. Destroyed, Degrees Fahr.‡					Hardness Before Destruct'n	Nature of Collapse		
Fireclay	Mineral 5 to 10% volatile (combined water) Incombustible	3000 to 3100	1	1	2 to 5	45 to 75	900 to 1000	Lowers	Lowers	Fairly hard	Some	Hard	Slow	Hard	Fair
Silica Flour	Mineral Non-volatile Incombustible	3100	½	3.6	.....	.....	.....	None	Lowers	Very hard	Some	Hard	Slow	Hard	Good
Cereal Binder	Vegetable Some volatile 99% combustible	Decomposes	4	3.5	60 to 70	48 to 56	500 to 600	Little	Lowers	Fairly hard	Some	Softens slightly	Gradual	Good	Fair
Dextrine	Vegetable Some volatile 99% combustible	Decomposes	2	7.7	50 to 60	62 to 72	500 to 600	Little	Lowers	Fairly hard Softer in center	Strong	Softens slightly	Gradual	Good	Fair
Molasses	Vegetable 30 to 35% volatile 95% volatile and combustible 5% ash	Liquid	½	...	40 to 50	36 to 45	400 to 500	Little (Ash may lower it)	Little	Hard Softer in center	Strong	Softens	Gradual	Good	Fair
Rosin	Vegetable 95% volatile and combustible 5% ash	Softens at 110 to 120	..	...	8 to 12	225 to 335	600 to 700	Little (Ash may lower it)	Little	Hard	Very little	Softens	Gradual	Good	Fair
Linseed Oil	Vegetable 99% volatile and combustible	Liquid	..	...	100	100	600 to 700	Little	Little	Very hard	Little	Hard	Rapid	Very Good	Good

*Based on clay as 1.
†Based on linseed oil as 100.
‡Refers to pouring conditions not baking conditions. See text.

Description and Source of Data Tabulated

Green Bond. The green bond figures are based on data accumulated from shop tests. The relative values for amount of green bond are based on the bond of a 1 to 10 mixture by weight of the material with dried Ottawa sand, mixed by hand with the moisture content which gives highest green bond for that material. The bond of a good grade Ohio fireclay under these conditions (Lindstrom test[1] with A. F. A. type bar—approximately 115 grams A. F. A. bond) is taken as a base and given unit value. The bond of each of the other materials was reduced to the same binder to sand ratio when necessary and referred to the base value given for fireclay.

The green bond of the materials having a value of about ½ is very close to the green bond of the moistened sand alone, so it is doubtful if these materials add any effective green bond.

The green bond of the materials used for dry strength—strictly core binders—is not considered significant at the moisture content, 6 to 8 per cent, used for core sands.

The relative cost of green bond is based on the cost of bond secured from one pound of fireclay which is given unit value.

Dry Bond. The dry bond figures are given with considerable hesitancy. Relative figures giving the range or order of magnitude are not so innocent as first appears, as we must have a definite value which we can stand by to determine the relative values. The writer's own data are from transverse tests with cores made under shop conditions, and therefore not so definite as to ramming and drying conditions as is desirable. A check on the relative values of most of the materials was secured by a comparison with published data in researches on core binders. In order to get relative values it is necessary that the research cover two or more materials tested singly with sharp sand on the same kind of machine and that the results be expressed in the same units. From the work of H. L. Campbell[2, 3] relative figures

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[1] Lindstrom, R. L., *Obtaining Molding Materials for the Steel Foundry*, A. F. A. Trans., vol. 29, 1920, pp. 202-212.

[2] Campbell, H. L., *The Qualities of Commercial Core Oils*, A. F. A. Trans., vol. 33, 1925, pp. 72-82.

[3] Campbell, H. L., *Methods of Determining the Properties of Cores Made With Cereal Binders*, A. F. A. Trans., vol. 34, 1926, pp. 558-566.

on linseed oil and typical cereal binders were obtained and from the work of C. A. Hansen[4] relative figures on linseed oil, rosin (in solution) and clay. The strength values were reduced to the basis of 1 of binder to 80 of sand by weight, which corresponds closely to 1 of linseed to 50 of sand by volume. Maximum figures, i. e., those based on best drying time and temperature and best moisture content, were used.

It was found that the ratios of relative values of bond corresponded fairly well with the ratios shown by the writer's tests, the actual strengths being higher for the cores tested under ideal conditions. On the strength of this check, the writer's values for molasses have been included though not checked by the work of others. His tests on rosin were made with the powdered material.

Linseed oil was taken as a base and 100 used to represent its dry bond value in the mixture given, 1 to 50 by volume, or 1 to 80 by weight. The values of the other materials reduced to the same strength mixture, 1 to 80 by weight, were referred to linseed oil at 100 and their value on this basis determined by simple proportion. The stronger materials—higher figures—were given a range in the table of 10 per cent and the weaker materials—lower figures—a range of 20 per cent above and below the figure determined.

The relative cost of dry bond is based on the cost of the weight of binder equivalent to one pound of linseed oil, the cost of which is given a base value of 100. These figures also are determined by simple proportion.

Cost Figures. The spread of the cost figures on some of the low strength binders is due to the 20 per cent plus or minus range used in fixing their bond values. The figures for some of the materials appear high, compared to linseed oil (and they may be incorrect), but it must be remembered that we seldom demand the strength from cores made from other materials that we do from oil cores, that our impression of the high binder cost of oil sand cores is based on a high strength core.

Cost figures will of course vary with market prices and with localities. Assuming the bond values correct, these figures are

[4] Hansen, C. A., *Some Properties of Core Oils*, A. F. A. Trans., vol. 34, 1926, pp. 577-610.

probably respresentative of the binder costs in a middle western foundry at the present time.

Destruction of Bond. The temperatures given for destruction of dry bond strength refer to the destruction of the bond in the mold by the heat of the molten metal and not to burning of cores or molds in drying. These temperatures are, of course, approximate and are put 50 to 150 degrees Fahr. above the temperature at which the bond begins to seriously deteriorate in baking.

Condition After Drying. The hardness of the core or mold after drying will vary with the moisture content and the strength of the mix. It indicates the ability of cores to stand handling and to retain their sharpness of outline and also gives some indication of the resistance to the cutting action of the metal during pouring.

Behavior of Bond at High Temperatures as to Hardness Before Destruction and Nature or Rapidity of Collapse. These are not very well known but plainly very important properties in their effect on the resulting casting. They largely determine resistance to shrinkage, ease of removal of sand and surface secured. The practical foundryman's judgment regarding them is quite good, as shown by his choice of materials for various jobs. The properties listed are an interpretation of this judgment and of the known properties of the materials.

Data of this nature are likely to have as a background the practice prevailing at the foundry of the observer, and probably have been so influenced in this case. In this connection, the materials chosen for discussion were those with which the writer was most familiar. The list of materials was not intended to be complete.

Ease of Removal and Surface Resulting. The ease of removal of sand and the casting surface resulting will vary with the proportion of binder to sand and with the presence of other binders. Two or more binders are often used in the same mix and the effect of one may predominate. Also, the size of the sand section and of the metal section greatly influence the temperature reached by the sand and hence the final result.

Discussion and Conclusions. There are several specific questions regarding use of materials which will be offered for discussion, some general deductions will be attempted, and some comments made and theories advanced on the happenings in molds and cores under certain conditions.

The questions which suggest themselves are:

1. Does rosin actually give a core flexibility or softness under heat?
2. Is there a cheaper material per unit bond than rosin which will accomplish the same purpose?
3. If rosin does give a core soft under heat, is it logical to use fireclay with rosin to give green bond since fireclay gives a bond which is hard at high temperatures.
4. Do rosin and oil actually give a better "peel" or a shiny surface on the casting? If so, should cores of this material be washed with silica wash?

High Temperature Materials

Analysis of the tabulated properties shows that silica flour and fireclay are the two materials which contain the least volatile or combustible matter and the largest per cent of mineral matter. Therefore they undergo the least change at high temperatures and are the chief ingredients used with silica sand in molds and cores which will be raised to high temperature by heavy metal sections or long exposure to the metal in pouring. Both fireclay and silica flour are used in molds and usually only silica flour in cores for these severe conditions.

In addition to having a high mineral content, fireclay withstands the highest temperature of any of the binders before losing its bond and even then the collapse or loss of strength is gradual. Silica flour has no dry bond strength, but gives the impression of strength by hardness and compactness. When bonded with molasses water or oil a high content of silica flour, like fireclay, gives the sand the ability to retain its shape and its collapse is very gradual, even after the oil or molasses bond is destroyed.

The other binders, unless accompanied by fireclay or a high silica flour ratio, are used for sand sections which will not reach a temperature sufficient to destroy the bond while the metal is still

molten. So these two materials, fireclay and silica flour, are the ones by which to judge our progress and our limitations in coping with high sand temperatures.

Some of the properties of silica flour have just been indicated. In high proportions it greatly decreases the permeability of the sand. It gives a sand mixture which can be compacted very closely and made very hard and impervious to metal. Such a compact core is quite difficult to remove in cleaning the casting. It appears to improve the ease of cleaning and the surface secured, when used in smaller amounts in oil bonded cores.

Silica flour does not tend to lower the fusion point of the sand as fireclay does. It only adds more finely divided material of the same fusion point. But we seldom have fusion of a good sand-fireclay mix, so it is doubtful if the beneficial effects of silica flour are due to any effect on the refractoriness of the mix. The improvement is probably due either to the slower collapse of the mold or core or to the greater closeness and hardness conferred by silica flour.

Fireclay, as stated, withstands the highest temperature of any of the binders before losing its bond. When the bond is destroyed, the change is evident by the easier erosion of the surface, but there is no collapse. Permeability cores (A. F. A. test specimens) of sand and fireclay mixtures, i. e., of facing sand, show considerable compressive strength after baking at 1600 degrees Fahr.—about 40 per cent of the maximum strength. The hardness begins to decline at about 650 degrees Fahr. but is still satisfactory at 850 degrees Fahr. These properties explain the desirability of fireclay for bonding dry sand molds. It will withstand temperatures sufficiently high to permit rapid and certain driving off of all gases, sometimes including the combined water of the clay itself, without collapsing. This is no doubt due to the large amount of incombustible or mineral matter in the fireclay. The bond or plasticity may be destroyed by driving off the combined moisture, but the bulk is still present in the sand mixture and the effect of compacting still evident.

But when the bond is destroyed the hardness declines and the mold surface is subject to erosion. Dr. Moldenke states that this decomposition of the clay bond is the cause of the cutting of the

sand at the gate in green sand molds with the consequent washing of sand into the casting.[5]

What we need then as an improvement over our present materials is a material which will retain its bond at very high temperatures, or which will cause the sand mixture to glaze at high temperatures or surface harden.

Fusion, Penetration or Vitrification

The question of whether or not fusion of the materials in sand mixtures actually occurs in the steel foundry was brought up earlier in this paper. As previously stated, it appears that the fusion point of the sand and clay mixture is well above the pouring temperature of the steel—3000 to 3100 degrees Fahr., according to the somewhat uncertain cone tests, as compared to a maximum pouring temperature of 2850 to 2900 degrees Fahr. for open hearth steel from the ladle.

Our sand-fireclay mixture is an impure silica-alumina mixture. If we take the lowest temperature at which a pure silica-alumina mixture begins to fuse—(1540 degrees Cent. or 2804 degrees Fahr. as brought out in the discussion of one of the papers presented last year[6]) we have a temperature range somewhat lower than our high pouring temperature range. But the steel must furnish the heat to raise the temperature of the sand mix to the fusion point and it is doubtful if steel leaving the nozzle between 2850 and 2900 degrees Fahr. will flow through the gate, fill a cold mold, surround a core and raise the temperature of the core to 2800 degrees Fahr. Of course, we have the influence of pressure and the fact that the sand mix is a poor conductor of heat on the one hand, but on the other we are not absolutely sure of our high temperature measurements, especially of our pouring temperatures within a range of about 50 degrees Fahr., so all of this is somewhat speculative.

The explanation more commonly given for cores seemingly fused and very difficult to remove is that the steel has penetrated the core, flowing in between the grains of sand, and that the hard

[5] Moldenke, R., *Permanent and Long Life Molds*, A. F. A. Trans., vol. 34, 1926, pp. 204-210.

[6] Trainer, D. W., *Some Experiments on the Refractoriness of Foundry Sands*, vol. 34, 1926, pp. 327-354.

core is a mixture of sand and steel. This view is supported by observations of shop men that the high silica flour-sand mixtures are most successful, in those cores surrounded by a heavy mass of metal, when the core is rammed or packed, layer by layer, giving a very hard and tight core.

Cores in which metal penetration has occurred and in which a mixture of steel and core material does occur, may at first be mistaken for examples of fusion of core sand materials, but when these cores show a high iron content on analysis, it is plain that penetration has occurred.

We hear repeated statements of cases of cores fusing, but, in most cases the writer has observed, cores which were very difficult to remove were found to contain metal. This frequently penetrates through the vents to the inside of the core so that the contour or surface of the core may be smooth when it comes out, with no indication of a mingling of metal and core at the surface of contact, and still the core may be shot through with steel.

The writer has thought that some cases of cores very difficult to remove might be examples of vitrification of the materials, rather than fusion, the fact that the material was confined as well as hard, accounting for the difficulty of removal, but all pieces of such cores which he has examined were found to contain enough metal to be magnetic, showing the metal penetrating the core caused the difficulty.

The vitrification point is slightly below the fusion point and vitrification would undoubtedly be promoted by the pressure to which the core material was subjected, so it is quite possible that vitrification may occur. If it does occur, the vitrified material, baked to a brick-like hardness, would be more easily removed if not confined, that is, if the cores could be made with a large vent or opening through the center or possibly with a soft sand center, and the metal kept out of these vents or openings. All of which brings us back to the opening comment that what we need is not usually higher melting point materials but better application of those we have.

Discussion

J. M. Sampson: I would like to ask Mr. Young if they in experimenting used other materials along with their silica flour to help hold it in suspension.

E. R. Young: We have at times used salt in an effort to increase the specific gravity. Once we used an air agitator. But at the present time we are not using any mechanical or air contrivance to keep it in suspension. In some of our experiments in attempting to get the silica wash to bond better we used various grades of clay. But our conclusion was that the old fashioned molasses water was pretty good. If we don't burn the molds in drying, the silica wash will not flake.

J. M. Sampson: We have been using a sand clay very successfully in our silica wash. It very materially increases the time it will stay in suspension. The clay we used is the same as the China clay our company uses in porcelain work.

Chairman R. A. Bull: I think the manufacturers of silica flour in the last two or three years helped the foundrymen solve their problems to some extent by producing their so-called flour to a much higher degree of fineness than they used to do.

Mr. Stermer: We ran some experiments on clay, endeavoring to inject clay into our sand in liquid form. And we ran for about a month some experiments with Wilkinite. We found it holds clay in solution longer than any other material we know of to mix with it, including water glass. But Wilkinite gives us very good results.

D. Evans: Was that clay or Wilkinite that was introduced?

Mr. Stermer: We mixed the Wilkinite with the clay.

Chairman R. A. Bull: What was described as Wilkinite is a commercial name for a material geologically called bentonite. As I understand it, bentonite is really a volcanic ash. It is termed a clay substance, but it isn't a clay. It is very interesting geologically. It is now being marketed and produced commercially by several concerns. Most of it, I believe, is mined in Wyoming.

A. N. Connoroe: The gentleman brought up a subject which I have heard quite a bit of discussion about, and that is the use of Wilkinite as a suspender or emulsifier of linseed oil with water. I was wondering if anyone here has had any experience along that line? We had no material success with it. Probably it wasn't mixed in the right way. It looks to me as though it ought to cause linseed oil to mulsify with water. But we weren't successful in using it that way.

Chairman R. A. Bull: I might answer Mr. Connaroe's question in so far as I can. I know of one steel foundry which has for some time been using Wilkinite in making a linseed oil emulsion and they are pretty thoroughly convinced that it is quite effective.

Mr. Stermer: May I ask Mr. Connaroe, do they mix that Wilkinite and linseed oil at its natural temperatures or do you heat it?

Mr. Connaroe: We mixed it at its natural temperature.

Mr. Stermer: Try heating it. We got a little better results by doing so.

A New Type of Mold Drying Oven

By G. H. Wright* and J. M. Sampson,* Schenectady, N. Y.

Nearly four years ago it became necessary to build an additional large car type mold drying oven in the steel foundry of the General Electric Company at Schenectady. Plans of the usual type of oil-fired oven were submitted for approval, but before acceptance could be obtained, the question arose as to whether or not the principles used in drying porcelain and other materials could be incorporated.

This involved drying in a more or less humid atmosphere, and keeping up a fairly brisk circulation of the atmosphere within the oven, at least during the major portion of the drying time.

Preliminary tests in a small oven seven feet square by eight feet high were made and showed promise. Later tests were made on a larger oven, and after two years of experimental tests we proceeded with the design of the present large oven.

This oven is approximately sixteen feet wide, thirty feet long, and eleven feet six inches high (inside dimensions).

Walls are eight inch gypsum block, with one inch white flame plaster inside and one inch gypsum plaster outside. The roof is composed of twelve inches of cinder concrete, the floor is twelve inches of concrete on top of dirt base. Doors are four-inch channel frames, covered with sheet metal and filled in between with a patented insulating brick.

The side walls contain ducts through which the air passes, down on its way to the interior of the oven and up as it returns to the fans and steam heating coils. The interior wall of this duct is composed of perforated steel plates as indicated on the drawings shown. On top of the oven these ducts are connected by well insulated conductors of two fan blowers and a steam heat exchanger of the type used for heating factory buildings. The air is heated in these two heat exchangers and is forced down the hollow wall or duct, and across the surface of the molds to the duct within the opposite wall.

*Steel Foundry Dept., General Electric Co.

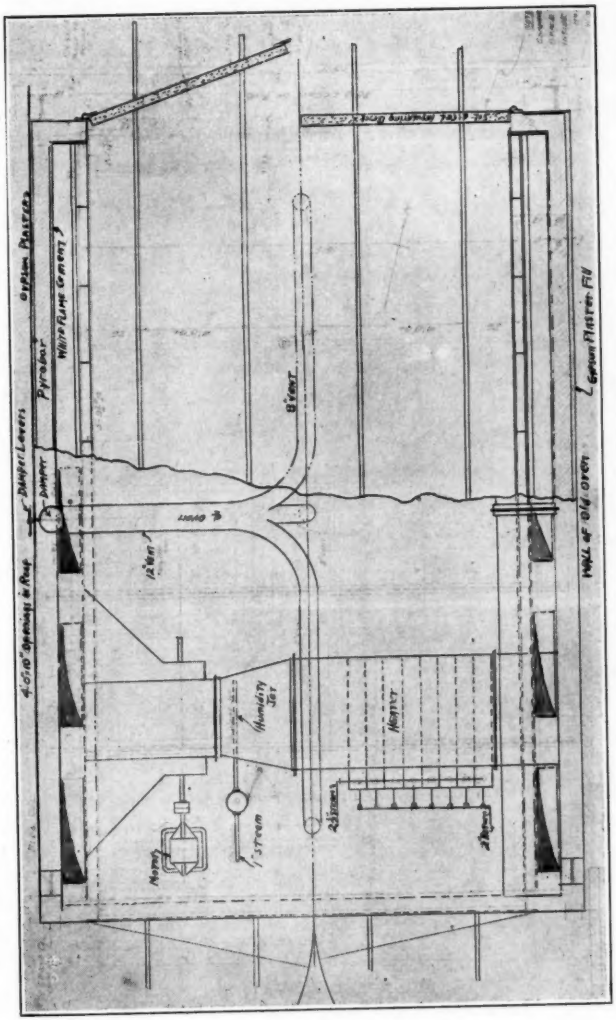

FIG. 1—PLAN VIEW OF OVEN

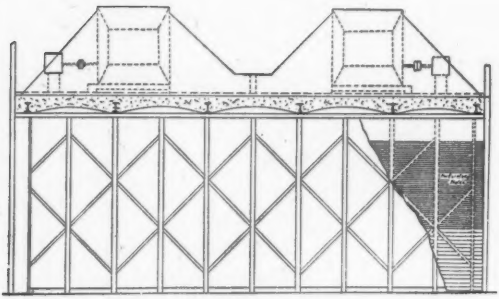

FIG. 2—SIDE ELEVATION

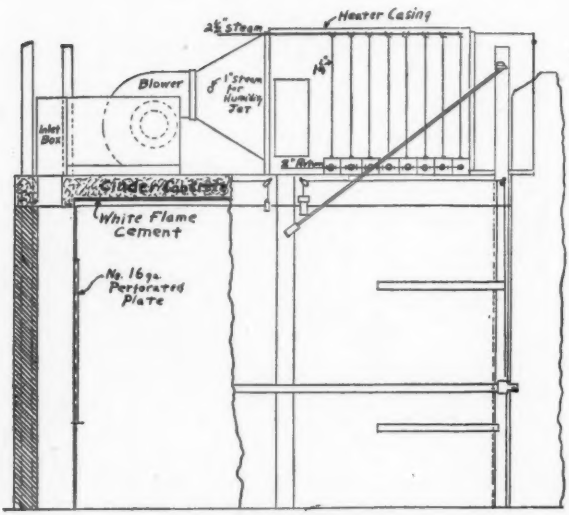

FIG. 3—END ELEVATION

When the steam heat is first turned on and the blowers started, steam is injected into the oven until the temperature of the center of molds reaches 180 degrees Fahr. This varies from two to four hours. This humidity prevents the skin or surface of the mold dying and assures a steady flow of moisture from the interior of the mold to the surface by capillary attraction.

Table 1

SUMMARY OF TESTS

Steam Heated Oven

Date, 1925	10/5	10/6	10/7	10/8	10/9
Hours Run	21.27	22.11	21.13	21.00	15.92
Weight of Sand, Tons	22.15	14.14	24.53	28.25	18.06
Weight of Iron, Tons	26.00	25.30	29.60	37.87	29.29
Total Weight, Tons	48.15	39.44	54.13	66.12	47.55
Total Pounds Steam Used	16,177	15,063	15,250	15,714	11,700
Average Steam per Hour	760	682	720	748	734
Total Cost of Steam	$7.44	$6.93	$7.01	$7.23	$5.38
Cost per Ton of Sand	$0.335	$0.49	$0.286	$0.255	$0.297
Dummy Mold Data:					
Per Cent Water in Sand	6.5	6.1	7.0	7.2	....
Depth of Drying, Inches	5	6	4	4.5	....
Temperature at Center, Degrees Fahr.	212	212	212	212	....
Hours to Reach This Temperature	14	13	15	18	....
Per Cent Moisture at Finish:					
2 Inches Deep	0.0	0.0	0.0	0.0	....
6 Inches Deep	1.0	0.3	1.0	1.2	....
10 Inches Deep	3.6	3.1	3.9	4.0	....

Oil Fired Oven

Date, 1925	4/20	4/21	4/22	4/24
Hours Run	16.00	16.00	16.66	16.16
Weight of Sand, Tons	18.20	21.80	27.20	32.60
Gallons Oil Burned	251	254	273	330
Average Gallons per Hour	15.6	15.8	16.4	20.4
Total Cost of Oil	$17.57	$17.78	$19.11	$23.10
Cost per Ton of Sand	$0.965	$0.815	$0.703	$0.708

Dummy Mold Data

Per Cent Moisture at Finish	Cold Part	Hot Part
2 Inches Deep	0.0	0.0
6 Inches Deep	1.8	1.0
10 Inches Deep	4.0	3.3

Cost Summary

	Steam Heat	Oil Fired
Average Cost Heating per Run	$6.80	$19.39
Average Cost per Ton of Sand	$0.317	$0.775

During October, 1925, a series of tests were made on this oven as well as on an oil-fired oven of same size located adjacent to it.

A recording flow meter was installed in the steam line leading to the heating coils, and the discharge line leading from the steam traps was carried to the outside of the building into two

barrels placed on scales. A small condenser was inserted in the line for cooling the condensate before it emptied into the barrels. The amount of steam consumed was found both by weighing the condensate and by integrating the flow meter charts. The amount of steam consumed as shown by the flow meter was 1.2 per cent higher for the week than that found by weighing the condensate.

Thermocouples were installed at different points in the oven and in a dummy mold which gave results as shown in the summary of Table 1. The dummy mold was thirty-six inches square and twenty inches high and was placed on the frame of the car in the corner away from the incoming air, so that it would be in the least advantageous position as regards drying.

The temperature readings in the mold were taken at the vertical center, two, six, and ten inches below the surface or top of the mold.

Readings of air temperatures within the oven were taken at the top center, in the corners of the oven eighteen inches from the floor and two feet from the doors, and also of the incoming and outgoing air in the ducts.

The weights of sand and iron (cars, flasks, bottom plates, etc.) in each charge we obtained by careful calculations of the cubical contents of these materials.

The oven is equipped with a vent pipe which is closed by a butterfly damper. This damper was closed during all the tests. Steam is piped to the inside of the heater casing for supplying steam to humidify the air.

The original speed of the motors which were direct connected to the fans was 1100 r.p.m. During these tests the speed was reduced to 550 r.p.m. for experimental purposes and it was found that the condition of the molds were not quite as dry as obtained from the higher speed. Consequently it was found necessary to return to the higher speed. A summary of the tests is given in Table 1.

Additional data is shown in the charts of Figs. 4 to 7.

Steam was used for heating the circulating air in this oven for various reasons. One was because the steel foundry is

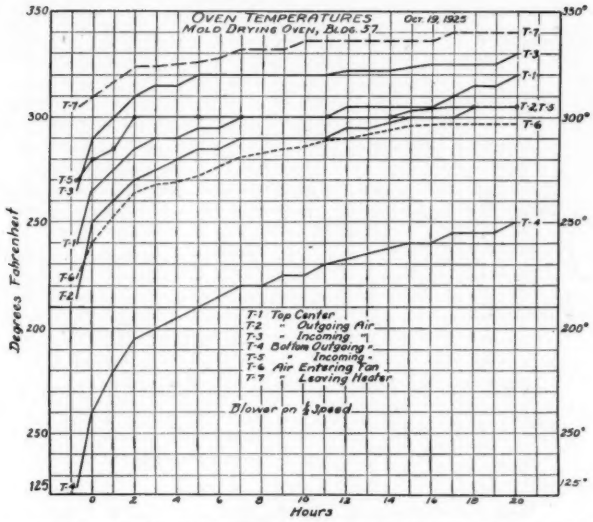

FIG. 4—CHART SHOWING TEMPERATURES IN VARIOUS PARTS OF OVEN DURING A 20-HOUR RUN—BLOWERS ON ½ SPEED

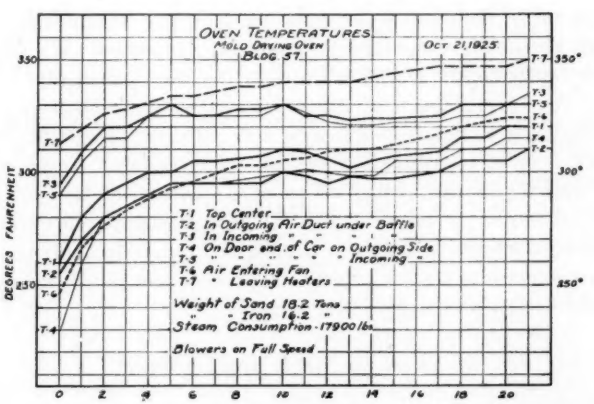
OVEN TEMPERATURES
MOLD DRYING OVEN
BLDG 37
Oct. 21, 1925
DEGREES FAHRENHEIT
T-1 Top Center
T-2 In Outgoing Air Duct under Baffle
T-3 In Incoming " " " "
T-4 On Door end of Car on Outgoing Side
T-5 " " " " " Incoming "
T-6 Air Entering Fan
T-7 " Leaving Heaters
Weight of Sand 18.2 Tons
" " Iron 16.2 "
Steam Consumption 17900 lbs
Blowers on Full Speed

FIG. 5—CHART SHOWING TEMPERATURES IN OVEN DURING A 20-HOUR RUN—BLOWERS ON FULL SPEED

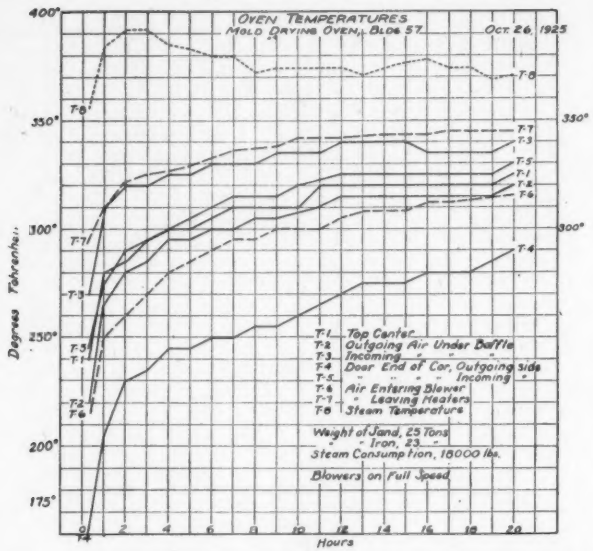

FIG. 6—CHART SHOWING TEMPERATURES IN OVEN DURING A 20-HOUR RUN—BLOWERS ON FULL SPEED

adjacent to the main boiler room of the plant, and also because, with the steam temperature running approximately 375 degrees Fahr., it would be impossible to overheat the sand molds.

It is recognized that many foundries would not have steam available in sufficient quantity or with sufficient superheat. However, it is perfectly feasible to heat the circulating air by means of indirect heating, using oil as fuel. Thermostatic control of the oil burner to prevent the oven temperature from exceeding 350 degees Fahr. should be provided, and provision made to introduce steam into the air current at a convenient point; this steam could be low pressure as well as not.

Effect on Molds and Castings

We find we can dry a given mold in nearly the same time interval, leaving practically the same or less residual moisture at a given depth, in this new oven as in the older oil-fired oven.

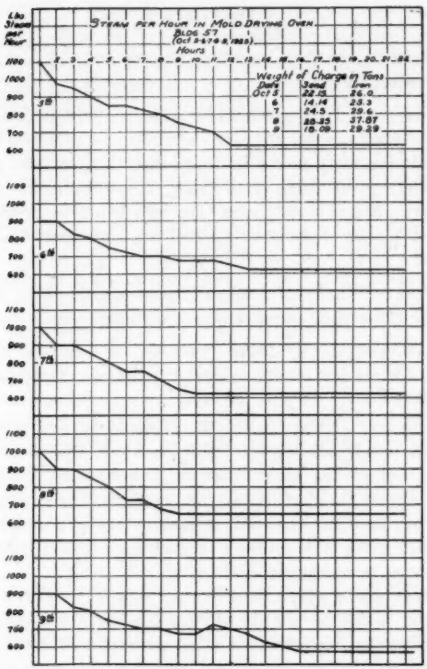
Steam per Hour in Mold Drying Oven
Bldg. 57
(Oct 3-4-7-8-9, 1923)
Hours
Weight of Charge in Tons
Date | Sand | Iron
Oct 3 | 22.15 | 26.0
6 | 14.14 | 25.3
7 | 24.5 | 29.6
8 | 22.25 | 27.87
9 | 15.09 | 29.29

FIG. 7—POUNDS OF STEAM PER HOUR DURING 22-HOUR RUNS

But there is no comparison between the sufaces of the molds dried in the new oven, with those dried in the older ovens. There is an entire absence of cracks in the surface of the silica wash coating, and even if one scratches away this silica wash, the sand below is found well bonded and free from any tendency to wash away with the metal during pouring.

The discounts in this foundry are running below 1.75 per cent of castings shipped, and it is seldom that a casting made in a mold dried in the new oven is found in the discount list due to mold cutting, scabbing, and other causes which can possibly be attributed to improper drying.

Discussion

W. B. Perry: Are these openings the entire height of the wall from the floor to the ceiling?

J. M. Sampson: They are graded. I am sorry, but you can't see them in this sketch. On page 04? the side elevation will give you some idea. At the right hand side there you will notice that about a third of the way up there is a fairly good sized slot, which is several inches long. Farther on up they are simply round holes, the idea being in having the opening greater at the bottom, that more of that air can come down through the bottom.

W. B. Perry: What is the amount of cubic feet of air that would pass across there for that low temperature, something like 20 feet per minute?

J. M. Sampson: If my memory serves me correctly it is somewhere around 18 or 20 feet per minute. That is velocity. How many cubic feet, I don't remember.

E. H. Ballard: I want to say there should be, and probably is, in the minds of some people considerable curiosity about this oven design. From what I have seen of the molds that have been dried, irrespective of the commercial value as to whether they are more or less expensive, there is a decided improvement in looks of a casting from a mold dried in this manner over any other way, unless a longer time has been taken and absolute control of drying temperatures had.

The keynote to the whole situation, particularly in dealing with medium or larger sized molds, is the freedom from surface changes. We were all familiar with what was obtained when we used to dry under the ordinary foundry conditions. It is a very, very important point and I think as time goes on we are going to come to recognize that feature. I think we are too hasty in some of our operations and that the one thing of quality alone is worthy of a great deal of serious thought.

Chairman R. A. Bull: That is a very interesting comment, Mr. Ballard, and one that has a lot of significance. I was wondering if the author in his comparisons had the opportunity of including molds dried in electrically heated ovens from the standpoint of the appearance of the molds?

E. H. Ballard: I don't think I have ever seen molds dried with any other fuel with the atmospheric conditions so changed as to approach the conditions Mr. Sampson is describing, that is to get that humid atmosphere in the early stages of drying.

Chairman R. A. Bull: In other words, the humidity is the significant thing.

E. H. Ballard: It seems to be the big factor.

J. M. Sampson: It is simply the introduction of steam at the early stages. I might explain that a little better by saying that our industrial heating engineer who started us on this thing first, had absolutely no idea of

what the final outcome would be. In fact, he thought we could simply take molds and put them into a porcelain humidifier, as they call it, such as we have at Schenectady. Mr. Wright and I took molds over there and tried to dry them in the porcelain oven at around 212 degrees Fahr. It was practically nothing but a steam finishing bath and the molds got absolutely no drying.

Later on we found a small 7-foot square, fairly well insulated oven and we tried drying with steam, later on elevating the steam pressure so we were using high pressure steam. And later on we put in a fan, simply a revolving fan. That immediately began to produce some results. And then we put in about four or five of these small fans, these wall fans, in this little oven and we got good results from that. We got much better results that way than with the single fan.

So we found there were two things that were necessary. One was a high degree of humidity in the early stages of the drying and the second was plenty of circulation of air. At the time we were running these tests we had a certain amount of vibration and we tried to reduce the speed from about 1,100 r. p. m. down to about 550 and we found we didn't get the same depth of drying in the unit in the same length of time that we did when traveling at higher rates of speed. Possibly if we used a higher rate of velocity, the air sweeping across the face of that mold faster would possibly dry it quicker than we did. Although there would be practically no use in doing that for you are pretty well limited to your 25-hour cycle, anyhow. So the whole thing is analagous.

If you are out driving your automobile on a hot day you don't suffer very much from the heat as long as you are getting a pretty good current of air going through your car, but the minute you stop and you get no breeze, you will find the perspiration coming into your face pretty fast. You take in the modern laundries they simply drive off the moisture from the clothing at a very low temperature. They have to or it will spoil your fabric. It is done by circulation. And we have the humidity simply as a preservative so as not to break down the capillary attraction in the surface of the mold.

Report of Committee on Heat Treatment of Ferrous Metals

To the Members of the American Foundrymen's Association:

It is the understanding of your committee members that we were originally organized to cooperate in a joint capacity with a subcommittee of the A. S. T. M. Committee A-4 to develop a Recommended Practice for the Heat Treatment of Steel Castings. Following the adoption of this Practice by the A. S. T. M., nothing further has developed until recently to demand the attention of our committee.

During the last year, however, the Joint Committee of the A. S. T. M., A. S. S. T., and S. A. E., which was appointed to clear up some of the confusion now existing in the use of heat-treating terms, has come to an agreement and submitted its report to A. S. T. M. Committee A-4, under the title, "Definitions of Terms Relating to Heat Treatment." The question of recommending this report to the members of the A. S. T. M. for adoption as a tentative standard was submitted to the members of Committee A-4 for ballot. The A. F. A. is represented on this committee by the chairman of your Committee on Heat Treatment of Ferrous Metals, and with practically unanimous approval of the latter committee, our ballot was cast in favor of presenting the above report for adoption. A copy of the joint committee report is attached hereto.

While the proposed "definitions" clear up many points where confusion now exists, no specific term has been included to designate that type of annealing common to the steel casting trade, and which consists in heating to some point above the critical range, followed by furnace cooling. It appears that the general term "annealing" as now used embraces a wide range of treatments, and the only way possible to clarify the situation was to designate and define the many sub-types of annealing practice. This has been accomplished in many instances, although as stated above, no term has been developed to cover the type of annealing with which the steel casting trade is most familiar. It is hoped that

the A. F. A. will state its desires in this respect, and the choice of a suitable term would constitute an activity of your Committee on Heat Treatment of Ferrous Metals within the near future.

While nothing has been attempted by our committee with regard to the treatment of cast iron, attention is called to a new set of data sheets on cast iron, now being issued by the American Society for Steel Treating. These sheets are a compilation of the best existing information on the manufacture of cast iron, together with the latest developments in the heat treatment of iron. The data are entirely informative, and should prove of special interest to members of the A. F. A.

The American Society for Steel Treating also has a committee at work in the preparation of a series of data sheets on the Heat Treatment of Steel Castings. While your association has no official representation on the above committee, the A. S. S. T. has given due consideration to the A. F. A. in making its appointments, and practically all the members of this committee are also members of the A. F. A. The final development of this work should lead to an increased interest in heat-treated castings.

Now, you will be particularly interested in the terms relating to heat treatment as they are defined by the Joint Committee.

ANNEALING *is a heating and cooling operation of a material in the solid state.*

Note (A) Annealing usually implies a relatively slow cooling.

Note (B) Annealing is a comprehensive term. The purpose of such a heat treatment may be:

(a) To remove stresses.

(b) To induce softness.

(c) To alter ductility, toughness, electrical, magnetic or other physical properties.

(d) To refine the crystalline structure.

(e) To remove gases.

In annealing, the temperature of the operation and the rate of cooling depend upon the material being heat treated and the purpose of the treatment.

Certain specific heat treatments coming under the comprehensive term "annealing" are:

A. NORMALIZING—*Heating iron base alloys above the critical temperature range followed by cooling to below that range in still air at ordinary temperature.*

B. SPHEROIDIZING—*Prolonged heating of iron base alloys at a temperature in the neighborhood of, but generally slightly below, the critical temperature range, usually followed by relatively slow cooling.*

Note: (a) In the case of small objects of high carbon steels, the spheroidizing result is achieved more rapidly by prolonged heating to temperatures alternatively within and slightly below the critical temperature range.

(b) The object of this heat treatment is to produce a globular condition of the carbide.

C. TEMPERING (ALSO TERMED DRAWING)—*Reheating after hardening, to some temperature below the critical temperature range, followed by any rate of cooling.*

Note: (a) Although the terms "tempering" and "drawing" are practically synonymous as used in commercial practice, the term "tempering" is preferred.

(b) Tempering meaning the operation of hardening followed by reheating is a usage which is illogical and confusing in the present state of the art of heat treating and should be discouraged.

D. MALLEABLEIZING—*Malleableizing is a type of annealing operation with slow cooling whereby combined carbon in white cast iron is transformed to temper carbon and in some cases the carbon is entirely removed from the iron.*

Note: Temper carbon is free carbon in the form of rounded nodules made up of an aggregate of minute crystals.

E. GRAPHITIZING—*Graphitizing is a type of annealing of cast iron whereby some or all of the combined carbon is transformed to free or uncombined carbon.*

Now those are the rather wide interpretations and definitions of annealing. Perhaps those ideas are somewhat new to the members of the Foundrymen's Association, but if we examine all

the technical data available we find that in general normalizing has been included in the scheme of annealing as one certain method of annealing. By referring to the A. S. T. M. Standard A 35-24, for annealing of miscellaneous rolled and forged carbon steel objects, you will find that for ordinary annealing, no definite type of cooling is specified, but that the method of cooling may vary, depending on the carbon content of the object, and also upon its mass. Thus high carbon stock is ordinarily furnace cooled, but if the mass is sufficiently large, it may be air-cooled. Air cooling is recommended as general practice for low carbon stock, except where the object is small, when it should be furnace-cooled. So that here we have one instance of the inclusion of air cooling as an annealing practice. And we do not believe it makes much difference whether it is considered as an annealing practice or not, as long as we understand the idea back of it.

Why is it we have such a wide definition for annealing? Of course, in annealing castings we are accustomed to follow heating by furnace cooling. We consider that to be annealing. But we all use chisels, for instance, in the steel foundry. These are usually a carbon tool steel. Often they contain a certain amount of alloy. Now the standard form of annealing those chisels and of putting them in a suitable condition for the trade is entirely a different operation from the annealing of castings and usually implies a temperature just under the critical point, with long soaking.

You use in the core room, for instance, soft wire. In the processing of that wire it also is annealed at a low temperature of approximately 1200 degrees Fahr.

Then you have another kind of annealing we might call strain annealing. No doubt most of you remember five or more years ago there was considerable agitation over the annealing of chains as a safety measure. And we were all told to go ahead and anneal our chains in order to get better service and make it safer for our workmen. Well, most of us went ahead and annealed that chain just as we would a casting. We had standard engineering instructions recommending that practice. And what happened? The chain became all scaled and when we put it in service it stretched like rubber. This indicates that if chains are to be annealed at all they should not be annealed as we anneal

steel castings. We should probably anneal them somewhere between 500 and 900 degrees Fahr. We find, therefore, that we have all sorts of applications of different types of annealing that we never thought of before. And that is what made it necessary to adopt this wide definition of annealing.

How are we going to define the ordinary annealing practice? We have talked to some of the members of this committee and they seemed very agreeable to define it as full annealing, because it accomplishes more than other types. If we refer to leading metallurgical authorities you will find this type of annealing referred to as being "true" or "full" annealing. And we find the same statement in many text books. So we think it would be logical to call this particular type full annealing. It will certainly indicate more than the unqualified term.

We might say in conclusion that when the report of this Joint Committee was submitted to the General Committee of the A. S. T. M., 30 members favored resubmission to the main body with three votes negative. The others refrained from voting. So that this proposition, too, is up before the convention of the A. S. T. M., which is to be held in a few weeks.

Respectfully submitted,

A. W. LORENZ, *Chairman,*
A. F. A. Committee on Heat-Treatment of Ferrous Metals.

DISCUSSION

J. H. HALL: I am a member of that Joint Committee and we were mighty glad to get Mr. Lorenz's favorable vote on our work so far as we have gone. There was a committee of four appointed from the A.S.T.M. to work with a joint committee. They got together with the representatives of the American Society for Steel Treating and the Society of Automotive Engineers and they had one grand fight for three years, and the whole basis of that scrap was that word annealing. Mr. Thieman, who is certainly a pretty good authority on metallurgical terms, was the man who held out that annealing was a very broad and general term and he proved it. I at first didn't want to accept his definition at all. But when Mr. Thieman got through submitting his authority, our opinion looked like thirty cents and we were through.

So the net result of the three years was to agree to quit and then a new committee was appointed. It was awfully hard, believe me, to get

people who were willing to serve on this Joint Committee, because it was a thankless task. And our final result was a compromise and we were obliged to define annealing as a broad, general process, because anneal is one of the oldest words in the English language and you can't tie it down to what we have been doing since Deutsches made his first steel casting. The word is too old and the meaning is too broad. We should have some specific word for the kind of work which we do.

I note there is a tendency to call it full annealing. That is going to meet opposition from the people who are mixed up in wire drawing. They raised an objection through Mr. Thieman about the effort to make annealing what one man called "Hi-nealing." They weren't going to be told they were not full annealing that product for their purposes, for they are.

It sounds very simple when the foundrymen are talking together, but when you get steel men of all kinds in one room around the table, you have quite a job. I, personally, would rather call it dead annealing in castings. To my mind, that describes it far better than full.

But we do desire earnestly that these terms be accepted provisionally as the best we can do now. Mr. Lorenz' vote which he has indicated on the part of the A.F.A. Committee I think is very wise.

Report of A. F. A. Representative on Joint Committee on the Investigation of the Effects of Phosphorus and Sulphur in Steel

To the members of the American Foundrymen's Association:

Your representative on the Joint Committee on the Investigation of the Effects of Phosphorus and Sulphur in Steel will confine this report to those phases of the joint investigation which relate to the product of the steel foundry, and which have not been covered in reports previously made to you.

Following the decision to eliminate the sulphur tests on steel castings, as reported at your 1926 convention, the joint committee, through its sub-committee on tests, gave extended consideration to the manner in which the tests to determine the influence of phosphorus in steel castings should be conducted. The joint committee gave the sub-committee on tests power to act regarding this matter, and appointed your representative as a member of this sub-committee, which held a meeting April 8, 1927, in Philadelphia.

At the meeting mentioned, it was decided that the tests will be confined to laboratory specimens machined from coupons on the ordinary form of test block as made in the steel foundry; that the material should be tested in three conditions, viz., annealed, normalized, and normalized and drawn; that tensile, impact, compression, fatigue, and torsion tests should be made, all at room temperature. It will thus be seen that no tests are to be conducted on steel in the condition as cast.

Four sets of specimens will be required for each kind of steel tested, one set to be tested at the Watertown Arsenal, one at the Naval Experiment Station at Annapolis, and one at the Bureau of Standards. Material sufficient for a fourth set of specimens will be held in reserve. The test specimens will be

machined at the Bureau of Standards where all heat treating will be done.

Because of the relatively large use of open-hearth steel for the manufacture of miscellaneous castings, the committee will confine the investigation to metal made in the open-hearth furnace; and because the commercial significance of a relatively high phosphorus content is far greater to acid steel than to basic steel producers, it was decided to employ acid open-hearth steel alone, the opinion being that test results from acid open-hearth steel may be reasonably accepted as applying to other foundry steels, with respect to the influence of the phosphorus content.

Since, broadly speaking, commercial steel castings are demanded ordinarily for properties calling both for moderate and for fairly large percentages of carbon, it was decided to make the tests on steels having two percentages of carbon, approximating respectively .25 per cent and .45 per cent; also to have all the steels contain approximately .70 per cent manganese, .35 per cent silicon and .045 per cent sulphur, with no special alloy being present.

The ranges of phosphorus desired are as follows: Class A (.25 per cent carbon), .025 per cent, .04 per cent, .06 per cent, .07 per cent, .10 per cent; and Class B (.45 per cent carbon), .025 per cent, .05 per cent, .07 per cent.

It is the intention that so far as possible none of the phosphorus shall be added in the ladle. In order to obtain a phosphorus content as high as .10 per cent it may be found desirable to add some phosphorus in the ladle, in which case precautions will be taken to get as thorough a distribution of the added element as possible.

For one complete set of specimens for each of three laboratories, plus sufficient stock for the reserve set of specimens, 12 bars 1⅛ inches square by 12 inches long will be required, for each heat treatment, for each chemical composition. Since there are three heat treatments and a total of eight chemical compositions, there will be required, all told, 288 bars of the size previously indicated.

The foundry or foundries selected for making the steel will not be placed under any inconvenient limitations that are not

obviously necessary to make the tests scientifically. The manner in which the test coupons shall be made will be prescribed by a sub-committee consisting of W. J. Corbett, representative of the Steel Founders' Society on the Joint Committee, John Howe Hall, representative of the National Research Council, the works manager or managers of the foundry or foundries selected to make the steel, and your representative.

It is obviously impossible now to predict with any degree of certainty what the tests will cost. We are proceeding on the reasonable basis that the foundry or foundries selected to make the steel should be reimbursed for the expenses incurred, from a fund accumulated for this purpose. It must be borne in mind in this connection that the Joint Committee has no funds with which to conduct tests for any phase of the joint investigation; and that the enormous amount of work done by and for the Joint Committee during the last eight years has been made possible only through generous contributions made by those representing the various industries involved thus far in this collective research, and by those in charge of government laboratories.

Without doubt, the surplus of most of the metal required for the tests can be utilized for the manufacture of commercial castings. However, it may be impossible to utilize any of the steel containing .10 per cent phosphorus for salable products, in which case the expense of producing that particular grade of metal will be relatively high.

A factor of importance as to the expense is a small melting unit. This will call for the selection of a foundry or foundries having small acid open-hearth furnaces where, of course, the committee must be assured in advance that good steel-making practice prevails, and where safeguards thrown around the manufacture of the test material will be strictly observed.

The procedure of the joint committee has been to have all material for testing purposes produced under the personal supervision of a Sub-Committee on Manufacture. This practice will be followed in connection with the steel foundry tests so that the joint committee may finally authenticate without undesirable qualification every important step relating to the research.

It has been very roughly assumed that the total amount of

$1,500.00 might be required for making the steel foundry phosphorus tests, exclusive of the heat treatment and the manufacture and testing of laboratory specimens, which will all be done in government institutions at government expense. Your representative has maintained a very close relationship with the representative of the Steel Founders' Society of America in connection with this entire matter, and the estimate of $1,500.00 represents our combined judgment at present. At the last meeting of the Steel Founders' Society held May 19, 1927, that organization very generously voted to put at the disposal of the Joint Committee one-half of the estimated sum required, or $750.00, representing what it regards as the proper share of the cost that ought to be borne by the steel foundry companies holding membership in that Society. This was a very gratifying action, indicative of the progressive spirit actuating the Steel Founders' Society.

Your representative proposes, subject to your approval, that the American Foundrymen's Association issue a circular letter soliciting contributions, addressed to all steel casting producers who do not hold membership in the Steel Founders' Society. Suggestions are desired as to this or any other method you might favor so that the burden of conducting the tests may be equitably borne by those who make the product now to be investigated.

It seems necessary to add but a few words regarding the commerial significance of these tests. It should be kept in mind that the joint committee's concern, from the beginning, has been devoted to service performance and not to difficulties of manufacture. It has been a common belief that steel containing more than .05 per cent phosphorus is dangerously brittle for many purposes. Probably this limit was established as a gradual process, in harmonizing the views of engineers who felt under the necessity of playing safe and who had had satisfactory experience with steels containing phosphorus up to and perhaps occasionally exceeding .05 per cent. We have not known where the danger line should be drawn. It is possible that the results of this investigation may demonstrate the satisfactory performance under severe conditions of one or both grades of steel (considered with respect to carbon content) containing appreciably more than .05 per cent phosphorus. If that should be the result, the cost of

satisfactory melting stocks should be lowered for the producer. Potentially, the investigation has considerable commercial significance for those who make acid steel castings.

Suggestions regarding any phase of this investigation will be appreciated by your spokesman on the joint committee.

Respectfully submitted,

R. A. BULL,

Representative of American Foundrymen's Association on Joint Committee on Investigation of the Effects of Phosphorus and Sulphur in Steel.

Foundry Blacking

By D. G. Anderson* and A. N. Ogden*, Chicago, Ill.

In foundry nomenclature, the term "Blacking" is interpreted to mean a carbon base refractory coating material suitable for covering the surfaces of mold cavities and cores. Blacking is also known as "black lead," "plumbago" and "graphite," and is so described due to the fact that the carbon base considered most satisfactory for blacking is graphite.

The graphitic form of crystalline carbon is found to be most satisfactory for foundry blackings and differs from the other forms of carbon in being extremely soft, possessing marked properties of adhering to surfaces, in its lower electrical resistance, and in having a relatively high kindling temperature. Examples of other forms of carbon are the diamond, charcoal, coal, lampblack and coke.

Through the courtesy and co-operation of our suppliers, an investigation was conducted to establish a test for evaluating the quality of plumbago blacking for foundry operation. The value of blacking may be measured by two characteristics; namely, adhering and refractory properties. Refractoriness is the ability of protective coating to resist the heat of the molten metal and thus prevent fusion of the metal with the sand or mold. The adhering properties, or the ability to stick to the mold, or sand, is of prime importance in foundry blacking as a coating would be of no particular value if it were washed away by the first onslaught of molten metal. This is especially true of blackings which are applied in the dry state and depend upon their natural adherent properties to adhere to the mold surface until the entire cavity is filled with molten metal.

A suitable carrier for plumbago blacking should not destroy its natural adhering properties, therefore, materials such as molasses are generally used.

*Foundry Engineers, Western Electric Co.

Chemical Test

The chemical method of evaluating quality of blacking was the first to suggest itself. Unfortunately there is no simplified chemical method available and this method, therefore, was not considered of particular value to the foundrymen for control purposes. The chemical method offers promise as a supplementary check test.

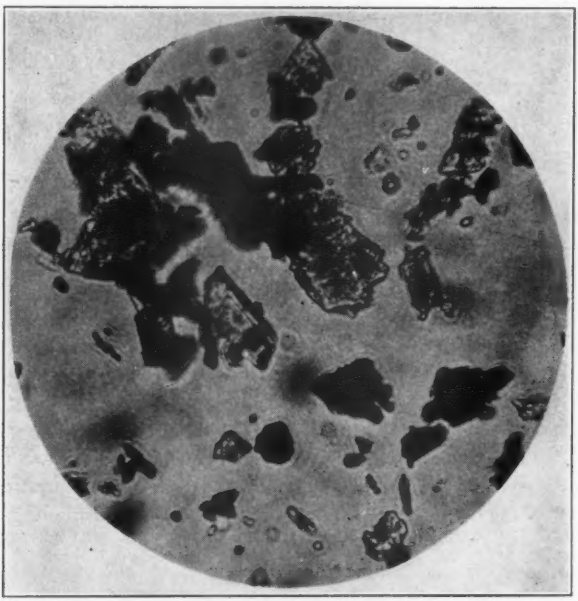

FIG. 1—MICROGRAPH OF IMPURE GRAPHITE SHOWING PARTICLES OF BOTH CRYSTALLINE AND AMORPHOUS MATERIAL —X750 REDUCED FROM 1000 DIAMETERS

Microscopic Test

Examination under the microscope at 1000 diameters shows quite plainly the difference between graphite and other constituents. However, the small sample under observation cannot be considered as representative of the lot and quantitative separation

on this basis is, therefore, of little commercial value. Two photomicrographs, Fig. 1 and Fig. 2, show the appearance of impure graphite and lampblack under the microscope. Fig. 1 is a photograph of impure commercial blacking, the graphite appearing as large shiny objects, and the other forms of carbon, etc., as dark dull objects. Fig. 2 shows a photomicrograph of lampblack at 750 diameters.

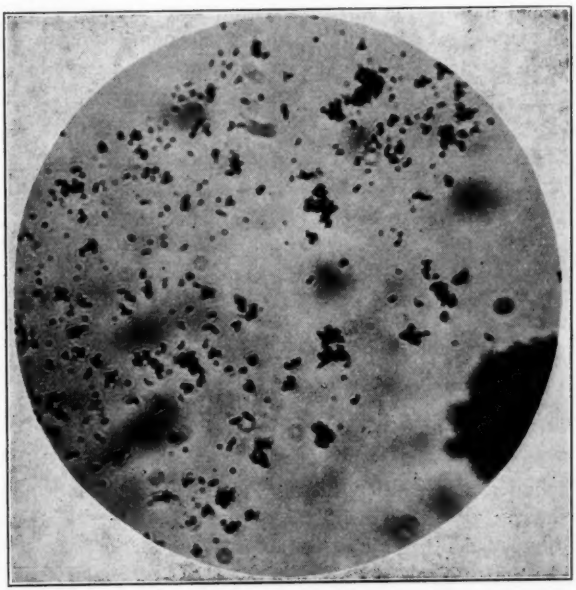

FIG. 2—MICROGRAPH OF LAMPBLACK SHOWING ONLY PARTICLES OF AMORPHOUS MATERIAL —X750 REDUCED FROM 1000 DIAMETERS

Electrical Method of Testing

It is seen that none of the foregoing methods of testing blacking are suitable for raw material control purposes in the foundry. The known difference in the electrical resistance of different forms of carbon suggests itself as a desirable and feasible test to be used for this purpose.

The following description covers the test which we carried out to establish a basis for determining the quality of foundry blacking by electrical resistance.

Weighed amounts of dry blacking were compressed to definite volumes and the electrical resistance then measured while under compression. After a few tests were made, we arbitrarily decided upon a 5 gram sample of blacking as the amount to be used as a basis for determining the electrical resistance of the compressed unit. The weighed sample was compressed in a ½-inch cylinder of hard rubber and after compressing to various degrees its electrical resistance was measured and recorded.

Table 1

Length of Pellet in inches	Resistance in ohms
1.68	6.94
1.62	4.48
1.56	3.88
1.50	1.805
1.43	1.265
1.37	0.903
1.25	0.702
1.18	0.570
1.12	0.407
1.06	0.335
1.00	0.165
.94	0.099
.87	0.071
.81	0.058
.75	0.046
.68	0.038

From these results, we feel that a 5 gram sample compressed as a cylinder 1 inch in length and ½ inch in diameter would possess satisfactory density for determining the electrical resistance for foundry control purposes. Based on these tests, and the performance of blacking in the foundry, it is concluded that blacking for our foundry purposes tested as described above should have an electrical resistance less than .200 ohms.

In Fig. 3, we have plotted the price in cents per pound of the blacking used in the various samples tested against the determined ohmic resistance. It appears that there is some relation between the content of high quality graphite in satisfactory blacking and the cost per pound. The fact that some of the samples tested did not fall on the curve indicates the commercial necessity for testing foundry blackings at all times.

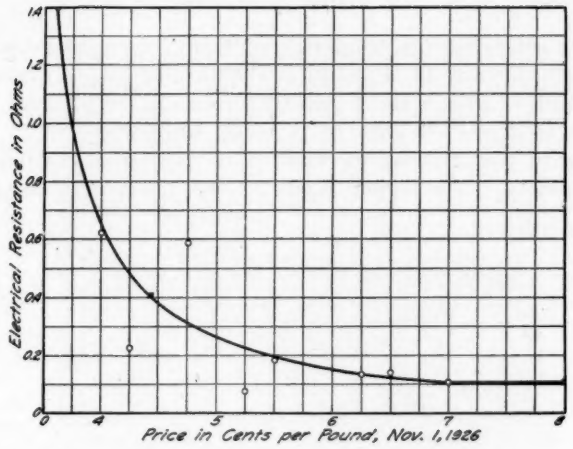

FIG. 3—GRAPH SHOWING RELATION BETWEEN QUALITY OF GRAPHITE AS INDICATED BY ELECTRICAL RESISTANCE AND COST PER POUND AS OF NOV. 1, 1926

Resistance Measuring Instrument

In measuring the resistance of the pellet, there are three different instruments which may be utilized; namely, the potentiometer, the Wheatstone bridge, and the direct reading ohmmeter. Obviously, the direct reading meter is the simplest in operation and most practical as it requires no balancing. Ohmmeters can be purchased which are guaranteed to have an accuracy of one-quarter of one per cent. It is our belief that this is well within the all around accuracy of the test and, therefore, can be employed for this work. These instruments, however, are not in such general use as the Wheatstone bridge, which hay be found in practically any laboratory. The Wheatstone bridge balances a variable known resistance against the unknown and is very accurate for all values above 0.1 ohms. This instrument, due to its accuracy, is considered more suitable than the direct reading ohmmeter. Its disadvantage compared to the ohmmeter is that its operation is slightly more complicated.

Description of Machine

It is believed that a brief description of the machine which we are using may be of interest. The machine (Fig. 4) consists primarily of a base and a journal suspending the pressure ram which is moved vertically by revolving hand wheel "A." The schematic sketch, shows the ram "B" in position at the time of compression. The bottom plate "C" and cylindrical container

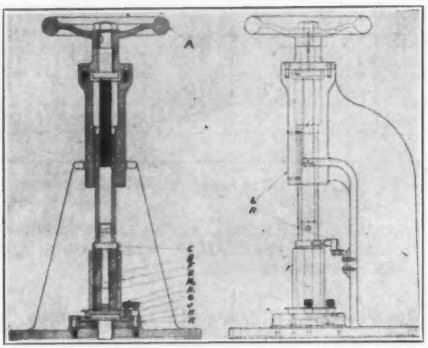

FIG. 4—DETAILS OF ELECTRICAL RESISTANCE MEASURING INSTRUMENT FOR TESTING PLUMBAGO

"E" and "F" are removed from the machine and five grams of the blacking placed in the one-half inch diameter opening. The receptacle is returned to the machine and the mass is compressed to a one-inch pellet. The height of the pellet is controlled to one inch by the stop on the ram as indicated at "C."

The bottom plate rests on a contact plate "J" on which is mounted one of the binding posts "N_2." It will be noticed that "N_2" is insulated from the frame "L," while "N_1" is connected directly to the frame. When the plunger is lowered the blade of a switch mounted on the shoulder "C" makes contact with the frame at "M." These contacts are both of hard drawn copper to insure a good connection. Connection is made from point "M" to binding post "N_2" through the frame itself. In this way bind-

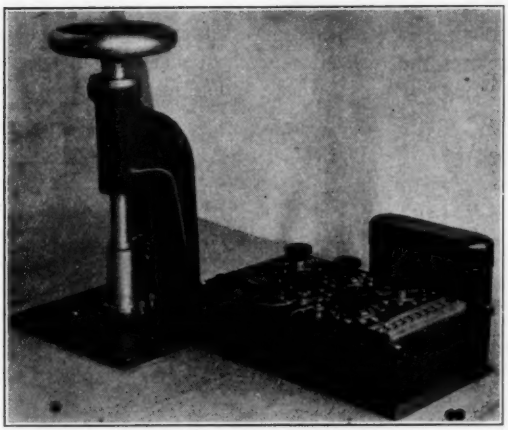

FIG. 5—ELECTRICAL RESISTANCE MEASURING INSTRUMENT WITH RAM AND CONTAINER IN PLACE WITH CONNECTIONS MADE TO RESISTANCE MEASURING APPARATUS

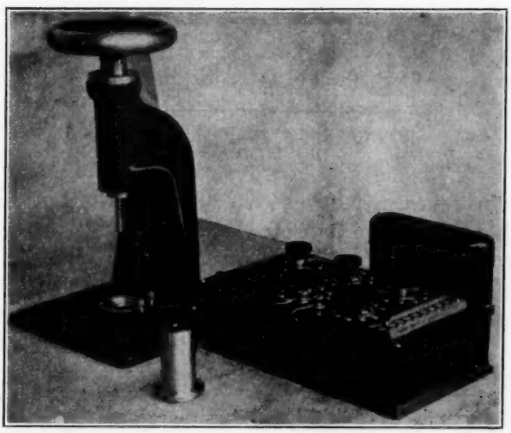

FIG. 6—ELECTRICAL RESISTANCE INSTRUMENT WITH CONTAINER SET TO ONE SIDE

ing post "N_1" is connected directly to the lower end and "N_2" to the upper end of the pellet.

An ohmmeter connected across these two terminals (N_1 and N_2) measures the resistance of the pellet plus the resistance of the connecting parts. However, should more exacting readings be

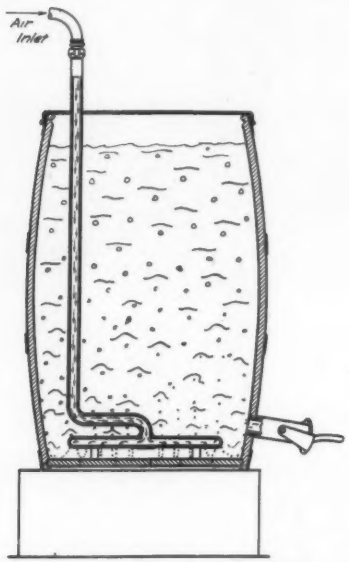

FIG. 7—DIAGRAM SHOWING APPARATUS FOR PNEUMATIC SUSPENSION OF PLUMBAGO

desired, the ram can be connected directly to the bottom plate "G" and the resistance measured which will give the resistance of the connecting parts alone without the carbon pellet. This reading may be used as a deduction factor for the final net resistance of the blacking.

Mixing of Wet Blackings by Pneumatic Agitator

Experiments were conducted to determine whether or not an agent could be added to the wet blackings in order to more effectively hold the plumbago in suspension, thus preventing it

from settling out. This investigation did not prove fruitful and we therefore devised a pneumatic agitator as shown in Figs. 7 and 8. It is made of three-quarter inch gas pipe, the air injector consisting of a pipe bent into a circular form and having holes

FIG. 8—OPERATOR MANIPULATING PNEUMATIC APPARATUS TO SECURE SUSPENSION OF PLUMBAGO

one-sixteenth of an inch in diameter drilled at 45 degree angles to each other. The air forced out through these holes bubbles up through the mixture and thus by constant agitation keeps the plumbago uniformly suspended throughout the entire mass of water and molasses. This device was found to be very satisfactory and consumed only a very small amount of air.

Conclusion

1. The data in the above report indicate that electrical conductivity may be used as a commercial test for evaluating blacking from the standpoint of the foundryman.

2. Blacking selected as satisfactory according to the electrical resistance test has been found suitable for wet application in the foundry when mixed with molasses and water and held in suspension by a pneumatic agitator.

Discussion

R. F. Harrington: The authors of this paper are to be especially commended because of their effort in the direction of the question of blacking and their effort to at least standardize in some sort of a definite way the characteristics of the particular blacking employed in their particular plant. It seems to me that there has been more sand blamed for roughness on dry sand castings, more iron claimed to have been too hot, and more molders abused for not having gotten on the right amount of lead or blacking than we can enumerate here today, when, after all, it had nothing to do with the sand, nothing to do with the method by which the molder put the lead on or the blacking on, or the temperature of the iron. It goes back to one fundamental thing, and that is the fact that the producer of the blacking may well have given the user the best blacking in the world for his particular job and then the user failed to use it in the proper manner. I venture to say that if we went through the average plant in this country, we would find that 95 per cent of the barrels or kegs or containers in which this blacking had been mixed would have a sediment of anywhere from an inch to ten or fifteen inches at the bottom, and one time we would get blacking on our mold that had plenty of lead or graphite or blacking in it, in suspension in water or molasses, as the case may be, and the next time we haven't anything but a little molasses, and mighty little protective medium. I think that that is a phase that we should give serious consideration to and not blame the producer of the product for the failure, because many times he is not to blame at all. We can give consideration to the question of a material to be added to the blacking, such as some high colloidal material, bentonite, for example, that will tend to keep that blacking in suspension, and then, in addition to that, take the added precaution of giving to the molder a pail of blacking that is the same today as it was yesterday and the same every hour of the day, and if we do that, we will go a long ways, I believe, toward the better appearance of our dry sand work.

E. D. Frohman: We are making a great many experiments on colloidal clays along the lines that Mr. Harrington has mentioned, and especially using the clays with oil, and we find by that method that we can keep the blacking in suspension. We have not gone up to the present time into work on graphites or plumbagos, but we have done a great deal of work on cokes and we find that the use of a colloidal material is the method for keeping your coke in suspension, and we now have a chemist working on the plumbago or graphite end.

J. T. MacKenzie: With coke blacking, just as Mr. Frohman says, we found that the volatile matter was the most important point in good castings from coke blacking. We ran hundreds of determinations of volatiles, ranging from, say, 2 per cent up to 7½, and we found that a very

quickly made, rough test which will show you in the neighborhood of the danger point on volatile is just to put about two or three grams of dry blacking in a flat capsule, such as is used for finding silicon determinations, into the muffle furnace with the door slightly open. At about 3½ per cent or above you get a flame, just a fleeting flame, while up to 7½ you get a very good flame. Below 3½ you get no indication of flame at all. I just pass that on for what it may be worth.

D. G. ANDERSON: I believe perhaps this electrical method may give promise of testing the difference between 48 and 72 hour coke.

MR. KERWIN: In making a study of blacking by this method I would like to ask the authors what is the effect of the fineness of grinding on blacking? Would it not be possible for, say, a coke blacking which was being ground very fine to give the same conductivity as the graphite blackings which were perhaps not ground so fine?

A. N. OGDEN: I hardly think that that would be possible, because coke is an amorphous form of carbon and is already in smaller particles than the graphite or plumbago formation. Of course, the whole principle of the graphite having a lower resistance is due to the fact that the particles are larger and that it has definite cleavage planes and they lie close together, and with the coke blacking the finer it was ground, I should say, the higher resistance it would have. We tried various forms of powdered coke and lampblack which was very finely divided amorphous carbon and found the resistance to be up around 17 to 20 ohms., while the resistance of a good quality of plumbago that is satisfactory for our work runs as low as .2 of an ohm.

R. F. HARRINGTON: Does or does not a blacking that contains some material similar to water glass or some material designed to put a coating on the surface of the mold tend in any way to increase the difficulties that might come about through buckling? It seems there has been some indication that a blacking that may be loaded up with material that tends to put a glazed surface to the dry sand mold may at the same time, under certain conditions, tend to increase the tendency of that mold to buckle.

D. G. ANDERSON: We do not use sodium silicate in blackings, only molasses and water. It seems logical that sodium silicate would cause the mold to buckle due to the contraction of the silicate during it solidification.

CHAIRMAN J. W. BOLTON: With the view of just trying to start a little further argument along this line, I wish to remark that X-ray measurements have shown that the Miller indices of graphite, whether the so-called amorphous form as obtained from gas coke or the more commonly termed crystalline form in graphite or in cast iron are essentially the same. Can we have any discussion along that line, any argument about the crystalline structure?

D. G. ANDERSON: During our study of blackings the X-ray machine was also employed; however, we have found no indications of crystalline formation under normal temperature.

A. N. OGDEN: We made tests on some lampblack and some supposedly amorphous material and found no indications of any structure at all. The machine has been laid up and we haven't had the opportunity yet to make the tests on our plumbago, which we are assuming is crystalline.

In Clarke's "Practical X-Rays," a test is described in which powdered coke was taken and the X-ray spectrum showed no structure, and after heating to very high temperatures, it gradually assumed the structure of graphite.

CHAIRMAN J. W. BOLTON: That is very interesting, inasmuch as in Germany and in Japan both they have taken all those forms and the ultimate crystal form is the same. The thing I was driving at is the fineness of grinding, the amorphous or colloidal, what you can get into colloidal suspension in your solution of molasses or water or flotation oil or whatnot, as compared to your more coarsely crystalline graphite.

Analysis of Four Hundred Tons of Defective Castings

By J. M. Haley,* Worcester, Mass.

The ultimate end of foundry research is the production of a maximum percentage of better castings at a minimum of expense. The control of raw materials such as molding sand, coke, and limestone, the control of cupola charges, and pouring temperatures are useful in so far as they assist in the attainment of a lower percentage of defectives and a better product. It is an undisputed fact that scientific control and foundry research has, in no small measure, brought about material reduction in foundry losses. It is concretely exemplified in the foundry records of those concerns who have definitely promoted its advancement. It is, however, a much mooted question among many as to just how much can be expected by expenditures in this direction and just wherein lies the key to the proper direction and line of attack.

Analysis of Scrap Heap Important

A thorough analysis of the scrap heap or the defectives, is the index by which concentrated energy may be expended. Segregation of defects, and classifications of these, relative to the source of complaint, enable coordination of thought and proper allocation of expenditures. Each particular foundry has its individual problems. Lack of floor space, inability to correlate molding floors and cupola with straight line production methods, extreme variability of casting shape and weight, and impossibility of standardization are some of the specific difficulties which prohibit many existing foundries from applying to themselves the advanced methods of modern procedure. It is quite evident that a foundry, situated to continually encounter the above difficulties, cannot utilize to the fullest extent those ideas and developments which contribute so materially toward more efficient operation in modern buildings.

*Foundry Technologist, Crompton and Knowles Laboratories, Crompton and Knowles Loom Works.

It is by scrap heap analysis and by the reduction of the scrap heap to a minimum that foundry control may be so exercised that these foundrymen are able to cope with the competitors who are not confined to the above limits. Defective castings not only play an important role so far as foundry expense is concerned, but an excessive percentage of loss is generally havoc-raising to shop production.

Defective Castings Classified

A study of conditions in a grey iron foundry, the average production of which approximates 80 tons per day, has revealed interesting data. Castings vary from one ounce to 6,000 pounds. These must stand wear and yet be easily machineable, so they will not hamper machine shop production. To fully study foundry conditions and establish a working foundation, the scrap castings were classified as shown in Table 1.

Table 1.

CLASSIFICATION OF DEFECTIVE CASTINGS

A. Foundry

1. Molders' Defects
   - (a) Cuts
   - (b) Drops
   - (c) Blows
   - (d) Not Run
   - (e) Coldshut
   - (f) Miscellaneous
     - (Core off center)
     - (Core crushed)
     - (Core tipped)
     - (Flask shucked)
     - (Strain)
     - (Bad patching)
     - (Runout)
     - (Core left out)
     - (Scabs)
     - (Hard ramming)
2. Shrinkage
   - (a) Shrink cavities
   - (b) Shrink cracks
3. Dirty Castings
   - (a) Sand inclusions
   - (b) Slag inclusions
4. Foundry Breakage

B. Machine Shop

1. Porosity
2. Dirt Inclusions
3. Blow Holes
4. Hard Iron

The analysis of four hundred tons of defective castings gave the results shown in Table 2.

Table 2.

ANALYSIS OF FOUR HUNDRED TONS OF DEFECTIVE CASTINGS

1.	Molders' Defects, per cent by weight:	
	(a) Cuts	2.35 per cent
	(b) Drops	7.92 per cent
	(c) Blows	5.00 per cent
	(d) Not run	7.30 per cent
	(e) Coldshut	8.13 per cent
	(f) Miscellaneous	38.10 per cent
	Total Molders' Defects	68.8 per cent
2.	Shrinkage	6.9 per cent
3.	Dirty Castings	17.4 per cent
4.	Foundry Breakage	6.9 per cent
	Total	100.0 per cent

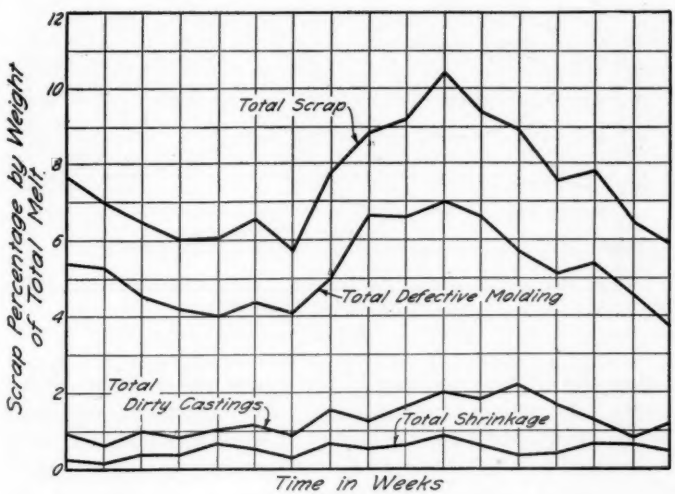

FIG. 1

Figs. 1 and 3 are graphs showing the variation of defective castings of the various classifications, week by week, for a period of sixteen weeks.

A study of these graphs clearly shows the tendencies of the total scrap. It follows very closely the total defective molding. Shrinkage and dirty castings do not vary materially. The graph of Fig. 2 shows the reason for the variance in the molders' defects. It varies directly as the molders' miscellaneous. In other words, the erratic percentages are due to the human element.

Molders' Defects

Over fifty per cent of the total defectives chargeable as molders' defects fall into the miscellaneous column and are attributed to the molder himself. The human element is a factor which, to a large extent, is uncontrollable. The inherent and overpowering desire to put up a few more flasks, at the expense of insuring each and every one to be clean, is a source of large loss in every production shop. The type of man who is employed in the foundry is not the artisan of former years; he is,

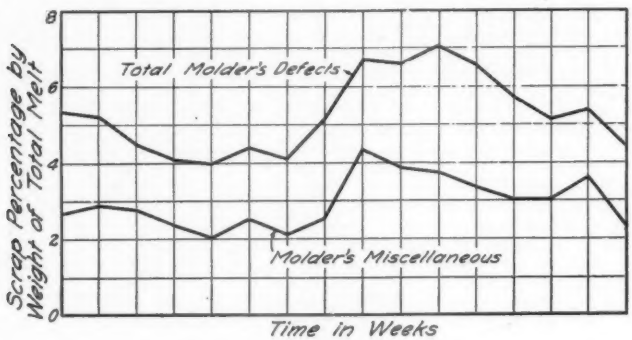

FIG. 2

rather, the ordinary common laborer whose vision centers on his wages. His actions are mechanical. His thoughts are measured by the quantity and not the quality of work accomplished. The exercise of care is submerged by the powerful impetus of speed. The problem involved in the elimination or reduction of this factor is an educational problem. It lies within the scope of the foremen to instruct and relay to these men that necessary care and pride in their work.

Approximately 22 per cent of the total molding defects, or 15 per cent of the total scrap, is classified as cuts, drops and blows. The reason for cuts, drops and blows may be fairly attached to molding sand ills. Lack of bonding material is responsible for drops. An excessively low permeability or high moisture content in tempering is a prolific source of blows. The quality of the bonding material has a direct bearing on the ability

of the sand to withstand the cutting and washing action of the molten metal.

Sand Control Plays Part in Reducing Losses

It is not intended to discuss the different properties of molding sand and their relation to the quality of the molders' heap. Suffice it to say, however, that the use of sand testing apparatus is of proved value in the rectification of the above complaints. Experiments have definitely shown that a very material reduction may be effected by proper manipulation and control. There are numerous examples of the benefits which have accrued. Investigation of those floors which were experiencing a large percentage of cuts and washes showed low values so far as dry sand strength was concerned. By taking the sand heap to a mulling machine, incorporating new sand and clay additions, thoroughly mixing and aerating, a decided increase in dry sand strength was obtained. Checking up in the foundry, it was found that these troubles were eliminated by this procedure.

Invariably, investigation of the properties of the molding sand yielded gratifying results. Troubles of the above nature had their remedy in proper consideration and correlation of sand testing to foundry practice. So far as blows are concerned, an increase in permeability will tend toward making the sand more "fool proof." Incorrect tempering and wet spots in the sand are again a factor of the human element and an educational program in conjunction with moisture determinations will bring about desired results.

Coldshuts and Misruns

Further analysis of the scrap heap reveals that 22.4 per cent of the molder's defects, or 15 per cent of the total defects, is attributed to coldshuts and misruns. Concentrated study of these items showed a certain class of castings that appeared regularly. These castings were thin sectioned or were thin sectioned adjoined to a heavy section. Coldshuts and misruns may be due to dull iron, improper gating or shape of castings. Occasions have arisen where men have poured iron which was being returned to the cupola. Although the molder knows dif-

ferently, the desire to have his work poured may overcome his better judgment and cause the loss of castings.

It may be said that dull iron or improper pouring temperature for the casting can be relieved by pyrometric control. The use of the pyrometer in the average shop is not warranted. True temperature readings are not easily managed. The personal element and judgment of the operator is a factor that cannot be minimized. Pyrometric control has its limitations. These limitations may truthfully be said to extend to exceedingly heavy and large castings. For the general run of castings, expenditures along these lines are not necessary. The judgment of the foundry foreman is sufficiently accurate.

Shrinkage

Shrinkage amounts to about 7 per cent of the total scrap. This is made up of contraction, cracks and shrink holes, especially in cored places. Analysis of this item indicated that the volume of shrinkage occurred in a certain class of castings that were chronic offenders. Just as regularly as these types went into the foundry, trouble was experienced. The cracks invariably were found in castings, the design of which was such that a heavy rim adjoined a light arm and heavy hub. The arms would generally pull away from the rim. Excessive losses from this source were experienced until a change in the design was made.

Design of Castings Sometimes at Fault

It is an undisputed fact that many castings are lost in the engineering department. Faulty design is an ill which takes an enormous toll of defective castings. Much time and energy and investigation are often employed in the foundry in an attempt to rectify a condition, the solution of which is an engineering proposition. A close relationship between the foundry organization and designers is absolutely essential for the production of intricate castings with the least amount of defectives. It should not be assumed that a casting, as designed, is not to be questioned. It should be recognized, however, that there are many opportunities for faulty design, if a competent foundryman is not consulted.

Shrink Holes Mostly Limited to Certain Patterns

So far as shrink holes were concerned, analysis of the scrap heap showed a problem of the same nature, namely, periodic offenders. Hence, an intensive survey of the defective castings enables proper attention to be given to those specific chronic offenders, which often constitute the biggest majority of defectives.

Dirty Castings

The third major item was that of dirty castings. This item totaled approximately 18 per cent of the defectives. This class of castings again revealed a problem of chronic offenders. Not only were certain castings troublesome, but investigation disclosed the fact that the majority of these castings came from a certain number of molders. Occasionally, there would be a general period of dirty castings throughout the entire shop, but usually the one group of molders and these particular castings were the source of difficulty. The big question to be solved was, of course, where the dirt came from. The coke and iron are invariably blamed, whereas the trouble is in faulty molding practice. The positions, the types and particularly the sizes of the gates and risers are responsible in the majority of cases of troubles of this kind. Iron will come from the cupola with a certain amount of kish and slag. It is a necessary evil attendant with cupola practice.

Cupola Operation Responsibility Limited

The cupola is a cheap economical process of melting and a high degree of refinement cannot be expected therefrom. On many occasions, the line of least resistance is to say that the correction of evils is in a change of the cupola practice. It must be understood, however, that any such change is limited by the very limits of the cupola itself. Metallurgical control and operation of the cupola can go no farther than to say the pig iron, the coke and limestone adhere to specifications, the blast pressure and volume are satisfactory. Operation is limited to the knowledge that the materials are charged properly, and that the ratio of coke is adequate. The accumulation of slag is incidental to operation. For the prevention of dirty castings, it should be

incumbent upon the molder to see that this slag does not enter the molds. This is done by skimming or straining or by properly sized gates and runners. Satisfactory proof has not as yet been given that gases picked up in the cupola are primal causes of gas holes in the casting. It is more reasonable to say that gases generated from the cores and from the molds themselves are responsible for many troubles of such a nature.

Chemical Analysis and Defectives

In the attempt to correlate defectives with the chemical analysis of the iron, at no time was sufficient variation found to warrant the assertion that a few points change in silicon or sulphur would cause erratic production. It is impossible to purchase pig iron within closer limits than plus or minus .25 silicon. It is accordingly logical to say that the chemical analysis of the casting cannot be controlled, except within corresponding relative limits.

Analysis of Machine Shop Defectives Proves Valuable

Investigation of defectives returned from the machine shop proves a very fertile field. Poor service records for cutters, the burning of tools and other similar complaints, very often constitute a serious charge against iron quality. Hard iron, in many cases, is a mythical charge. Invariably, laboratory examination discloses the fact that the iron could be classified as readily machineable. Brinell hardness values and structure disclaimed charges of hardness. Chemical analysis indicated proper percentages of the different constituents. It was found by checking machine shop practice that the speeds and feeds were greatly in excess over recommended practice. By proper adjustment of these factors and by intensive study, the hard iron charges became a matter of slight concern. Not only were speeds and feeds subject to correction, but it was found in many instances that the castings had not been cleaned properly. Burnt sand adhering in corners and crevices was a factor causing machine tool difficulty. Upon the exercise of more care in the cleaning room, this complaint disappeared.

Close Study An Economic Necessity

The vast amount of direct constructive development which results from proper segregation and intensive study of the different constituents of the scrap heap are of paramount importance. Waste is a matter of growing concern to industry in general. The Government is taking precautionary measures. It must be recognized in the solution that the human element is a most vital factor. The entire personnel of an organization must be educated to conservation and reclamation. Executives and superintendents must recognize the necessity of adhering to outlines and drafts made available by technical experts. The laborers themselves must take cognizance of the loss encountered in spoiled material and useless labor. With particular reference to foundry conditions, the scrap heap analysis is a workable index to efficient operation. It might truly be called the barometer of efficient production. By intimate knowledge of its parts, there is readily available information whereby we can direct and concentrate forces toward the reduction to a minimum of those castings which are perennial offenders.

Cast Chaplets and Tinned and Untinned Core Irons[1]

By Jacques Varlet,[2] Seraing, Belgium

Coated and Uncoated Steel Core Bars

In order to be able to determine the difference between core irons coated with tin and core bars of mild steel—which may represent either double chaplets or bar chaplets used in cored castings for wedging and supporting the cores, either of small or large dimensions, we proceeded as follows:

1. Bars 12 m.m. (0.472 inch) in diameter coated with tin and similar untinned bars were placed in square test molds 50 x 50 and 40 x 40 x 200 mm. (1.969 x 1.969 and 1.575 x 1.575 x 7.87 inches).

2. The molds were made for top pouring in the case of Figs. 1, 2, 3 and 4.

3. The test pieces marked A in each figure represent the bars placed in the molds into which a volume of iron suitable for engineering purposes representing a weight of 70 kg. (154 pounds) was poured for one minute by means of small hand ladles, the mold being kept continuously filled.

4. The test pieces in the same figures marked B formed part of the same flask and were connected to the A test piece by a bottom gate. They were therefore subjected to the same operation and received the same quantity of metal, but by bottom pouring. Fig. 5 shows how these test pieces were made.

Figs. 1 and 3 are those in which the core irons were untinned, while Figs. 2 and 4 represent those of the irons coated with tin.

Numerous tests, made with the greatest care, showed that the tinned iron fuses badly and produces a large number of blisters at the junction of the iron with the tinned part, as may be seen from Figs. 2 and 4.

[1] Exchange paper of the Association Technique de Fonderie de Belgique.

[2] Vice-President, Association Technique de Fonderie de Belgique.

FIG. 1—TEST MOLD—UNTINNED CORE IRONS

FIG. 2—TEST MOLD—TINNED CORE IRONS

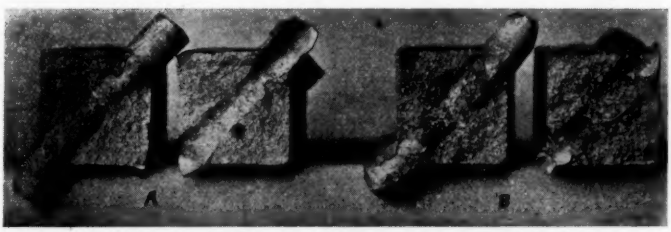

FIG. 3—TEST MOLD—UNTINNED CORE IRONS

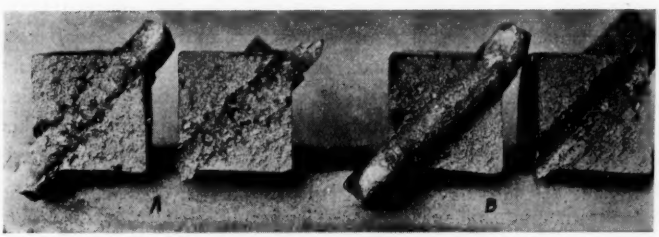

FIG. 4—TEST MOLD—TINNED CORE IRONS

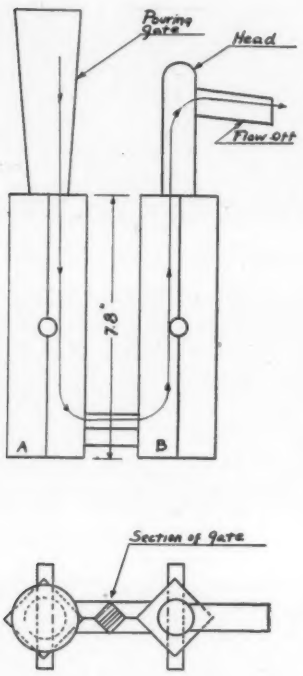

FIG. 5—DIAGRAM SHOWING METHOD OF POURING TEST MOLDS OF FIGS. 1 TO 4, INCLUSIVE

The test pieces which were cast directly—that is by top pouring—are not so good as those which were bottom poured in accordance with the diagram of Fig. 5. This test shows that by direct pouring, notwithstanding all the precautions taken to keep the pouring gate and the mold continuously filled during casting, air is nevertheless drawn into the mold and oxidation thus takes place on contact with the iron. With all the precautions taken to prevent the admission of air into the molds, and particularly when the pouring period is fairly long, it would nevertheless appear that the first entries of air are completely evacuated in 10

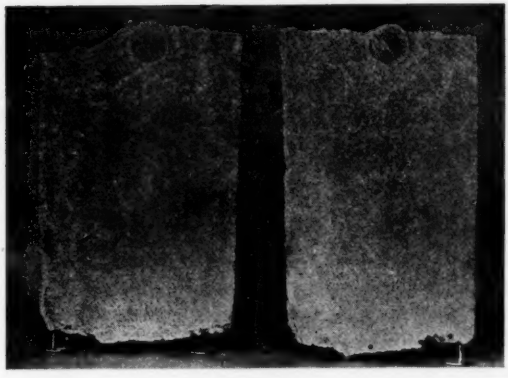

FIG. 6

to 15 seconds. But the same defect is reproduced at each test, whereas it is not produced by bottom pouring except on test piece B of Fig 1, where it is insignificant in comparison with the tinned and untinned irons obtained by direct pouring.

The analyses of the irons are given in Table 1.

Table 1

	Before Pouring		After Pouring	
	Tinned Iron	Untinned Iron	Tinned Iron	Untinned Iron
Silicon	0.085	0.005	0.141	0.141
Manganese	0.428	0.428	0.370	0.340
Sulphur	0.032	0.040	0.064	0.048
Phosphorus	0.095	0.080	0.243	0.220
Carbon	0.070	0.080	0.070	0.080

Remarks: There was no recarburization as a result of contact with the metal, but there was an increase of silicon and phosphorus.

Micrography. Fig. 6 represents two of these A test pieces of Figs. 1 and 2 cut in wedge form so as to show the cross section of the iron. The first is that of the tinned iron and the second that of the untinned iron test pieces. It will be observed that the untinned iron has a better appearance and fuses better than the tinned iron.

Conclusions. From these repeated tests it may be concluded:

1. That when tinned chaplets, double or with bars, are used, they must be of good manufacture, and that the iron must be pickled before the chaplets are tinned.

2. That if untreated irons are used as chaplets, particularly with bars, they must be well cleaned and must have all the oxide scale removed before use. This work must be carried out so that the bars may be placed in the molds with the minimum of delay before pouring.

The tests show a very marked advantage of the polished iron over tinned iron, even with pure tin, for it fuses much better and does not produce the blisters formed by the tinned bars. Iron suitable for engineering purposes was used. Its chemical characteristics being:

Silicon	Manganese	Sulphur	Phosphorus
1.80	0.6	0.07	0.3

and its physical characteristics:

Shock test piece: height of drop 60 cm. (23.62 inches) with a 12 kg. (26.5 pounds) tup. This gave the following results after 8 shocks repeated at intervals of 5 centimeters (1.97 inches):

Initial height of drop...250 mm. (9.84 inches)
Rupture .....600 mm. (23.62 inches)
Number of shocks..... 8
Work developed in kilogrammeters .....40.800 295,000 lt. pounds)
Strength per sq. mm. of section ..... 3.825 kg. (5439 pounds per sq. inch)

These particulars are given in order to show that the metal used in the tests was such as to give every possible guarantee.

Cast Iron Chaplets

The same tests were repeated on cast chaplets of various forms as shown in Figs 7 and 8.

The cast chaplets (A and B, Fig. 7) were placed in the 40 x 40 x 200 mm. (1.575 x 1.575 x 7.87 inches) test mold.

The test was poured horizontally with a volume of metal amounting to 20 kg. (44 pounds), the metal issuing from the mold by a riser and flowing through the riser until 20 kg. (44

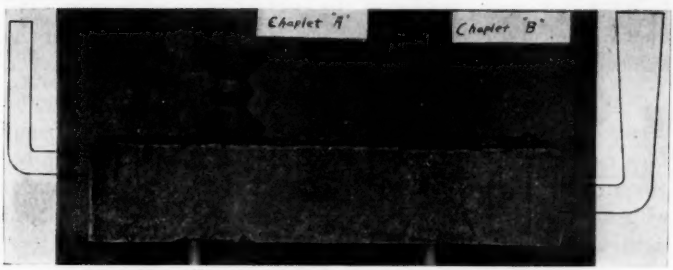

FIG. 7

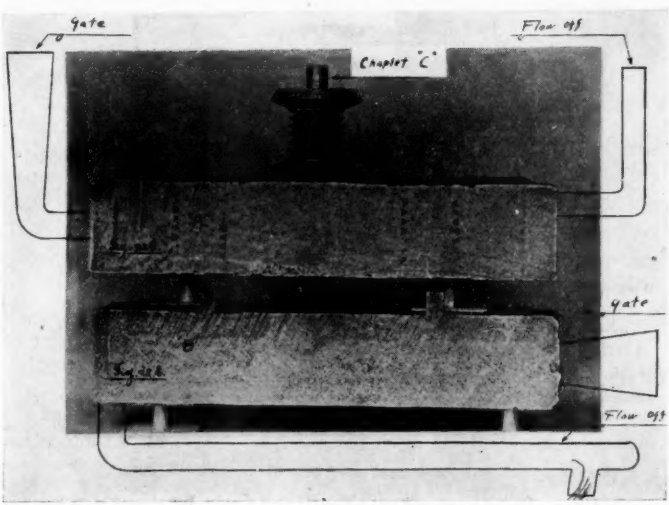

FIG. 8

pounds) of metal had been poured into the test piece. It will be seen that these two chaplets are almost completely fused, particularly A of Fig 7.

The chaplet of the form of B, Fig. 7, is the chaplet which has frequently been adopted by inexperienced founders and which ought never to be used, for, although it shows a suitable surface at the two ends for supporting the cores, the center of the chaplet,

forming two cones, cracks on the casting being withdrawn, and the two conical parts may easily come out of the casting under the influence of shock, vibration or pressure.

While the photo does not indicate a crack in the center, by means of a magnifier it was possible to detect on the casting some very narrow cracks caused by the contraction, which are the beginnings of rupture, while chaplet A is embedded in the metal with the maximum degree of adherence owing to the six conical parts with which the chaplet is provided.

Fig. 8, test piece A, was cast in the same manner as that in Fig. 7, with straight chaplets of the same metal and the same weight.

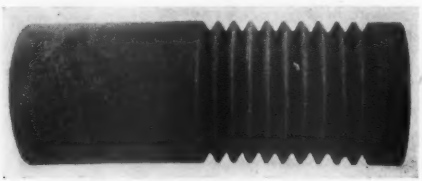

FIG. 9

The photo indicates poor welding between the metal and chaplet. This shape also is not to be recommended, particularly for light and thin castings.

Test piece B is top poured with the same chaplets and a volume of metal of 70 kg. (154 pounds). It will be noted that it is perfectly fused and that the result is excellent.

Test pieces were cast in the same manner with chaplets A and B of Fig. 7, and the same result was obtained.

Important Note: It should be specially noted that the numerous chaplets tested by us were of different metals, their analyses being as follows:

No.	Silicon	Manganese	Sulphur	Phosphorus
1.	2.56	0.642	0.024	1.63
2.	2.00	0.870	0.040	0.50
3.	1.40	0.700	0.040	0.045

We found that the No. 1 chaplets fused admirably owing to the very low melting point of the metal and its phosphorus content.

No. 2 also behaves fairly well and is stronger when the thickness is considerable, while No. 3 scarcely welds at all owing to the purity of the metal and the high melting point of hematite iron. Table 2 gives the analyses before and after pouring.

Table 2

ANALYSIS OF THE CHAPLETS BEFORE AND AFTER POURING

Before Pouring

No.	Silicon	Manganese	Sulphur	Phosphorus
1	2.00	0.6	0.05	1.4
2	1.75	0.5	0.06	0.5
3	1.40	0.45	0.07	0.045

After Pouring

No.	Silicon	Manganese	Sulphur	Phosphorus
1	1.87	0.5	0.06	1.07
2	1.75	0.5	0.07	0.55
3	1.40	0.48	0.075	0.15

There has therefore been a loss of silicon and phosphorus in No. 1. No. 2 has remained approximately the same. No. 3 has been affected by the phosphorus of the metal poured.

The analysis of the metal used for pouring on these chaplets was silicon 1.7 per cent, manganese 0.7 per cent, sulphur 0.07 per cent and phosphorus 0.95 per cent.

Fig. 9 represents a chaplet used to hold the core of an hydraulic piston, as shown in Fig. 10. The height of pouring head is four metres (13.12 feet). Notwithstanding this height of drop, the chaplets, which were of hematite iron, did not weld, and they were withdrawn from a broken casting, as shown in the photograph.

Conclusion

These tests have served to convince us that cast iron chaplets must be adapted to the character of the castings—their thinness or thickness, the volume of metal to be poured into the mold, the rapid or slow flow of the metal in contact with the chaplets, the volume and weight to be supported, etc. We are convinced that chaplets of very mild and high phosphorus cast iron, such as No. 1, will not stand very long the continuous

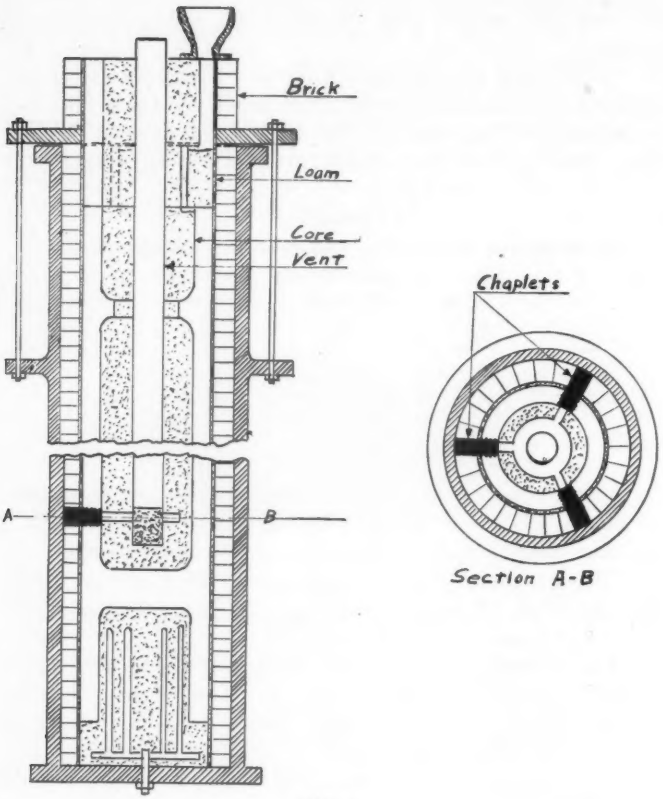

FIG. 10

flow of a metal at a temperature of 2100 degrees Fahr., for example. They will be completely melted in a minute and will be of no further use, except in the upper parts of the mold, where the flow of the metal is less constant and of shorter duration.

On the other hand, the chaplets of the analysis of No. 2, being more refractory, soften more slowly and are welded to the casting metal.

The chaplets having the analysis of No. 3 can be used only for castings of great thickness and requiring very heavy cores. In general, however, all the repeated tests show that this metal fuses with difficulty, even when the flow of the metal is continuous. It is nevertheless useful, and should be used for certain castings which are subjected to very great stresses.

Generally speaking, the founder must calculate—apart from the character of the metal—the dimensions of his chaplets, for their volume must be proportional to the volume and weight which they have to support, and particularly to the quantity of the flowing metal or the volume with which they are surrounded.

One must judge approximately whether, according to their dimensions, they are liable to soften and break or whether they are capable of supporting their load or even fusing with the metal without softening too much. It is therefore a question of the volume of the chaplet. A good result will be dependent upon all these factors.

Discussion

H. W. Dietert: I was very much interested in the conclusion reached on page 06?, that when tinned chaplets are used, the iron must be pickled before the chaplets are tinned. We use tinned chaplets, and sometimes we get what we term a chaplet blow. It has been the practice to call that oxidized iron, but it wasn't oxidized iron, it was the chaplet itself. The way to get rid of the trouble, at least the way we did, was to take the chaplets, place them on an old molding shovel, put it over a fire, heat it red hot, about all the shovel will stand, then dump them in a bucket of kerosene, and keep them in there until we use them. We then have no more trouble with them.

H. M. Lane: The same trouble comes in another line. In making mining sheaves and these cast iron hub wheels and quite a variety of work of that kind we have the spokes which must be thoroughly knitted into the structure, and in those cases we have always found that we had to treat them in some way. The primary object was to get rid of the scale and then dip them in red lead or kerosene, as you have, or linseed oil or in tin. All the methods got rid of the blows, but the prime essential was to have the bar itself clean.

A Study of Cupola Lining Refractories

G. S. SCHALLER,* SEATTLE, WASH.

Cupola linings have, for the most part, received less consideration in the modern foundry scheme than any other important foundry raw material. The reason for this condition lies, apparently, in the direction of the foundryman's willingness to accept most any type of fire brick for the cupola because operating conditions and temperatures within the furnace are not fully known. To be sure, fairly accurate data are at hand regarding the operating temperatures, yet information of this type is not complete enough unless it is accompanied by the actual facts of operating conditions such as insulation, load, slags, etc.

The generally accepted idea of a refractory material is one that will withstand a definite degree of heat. According to the specifications of a refractory material as set forth by the A. S. T. M. the material must have a minimum cone fusion of Seger cone No. 19, which corresponds to a temperature of 2768 degrees Fahr. The Bureau of Standards in Master Specifications No. 335a, places the softening point at cone No. 31 approximately 3056 degrees Fahr. for fire clay brick, which is the accepted type of material for cupola linings. In defining the term "refractories" two distinct aspects must be kept in mind:

1st. The resistance to the action of heat without regard to surrounding conditions.

2nd. The resistance to the action of heat in actual service.

It would seem that the second condition is of the greater importance to the foundryman.

Refractory materials are divided into three general classes, viz., acid, basic and neutral, dependent upon their chemical composition and the type of reaction set up by their uses under service conditions. So far as the cupola is concerned, little or no attention need be paid these classifications, although their importance in steel making furnaces is common knowledge. The usual type of

*Department of Engineering Shops, University of Washington.

fire brick refractories used in the cupola contains a silica (SiO_2) content up to 65 per cent calculated on dry weight. The other important constituent being alumina (Al_2O_3), which shows a variable content but may be taken at about 25 per cent minimum. The higher the latter content, the greater the refractoriness of the material considered under paragraph (1) of the definition of refractories. It will be seen, then, that fire clay brick are of the acid type of refractories. This fact is of great importance in studying their behavior in the cupola.

In order to study the failures in cupola linings, it is necessary to consider completely all operating conditions and note the different types of failures to which the refractories are subjected. Many of these failures are common to installations other than cupolas, consequently the more general types will be considered first.

Failure Under Load

A cupola lining is not seriously affected by load when the lining is installed as segments resting upon brackets spaced at not too great a distance. Theoretically, the only load sustained by any part of the lining is the dead weight of the short column of brick that extends to the next bracket—yet this becomes important at elevated temperatures, especially when the softening range of the brick is approached. The subject of failure under load has been studied by M. C. Booze and presented as technologic paper No. 2 of the American Refractories Institute. Some of the conclusions which Mr. Booze points out are:

1. "The load test should not be used for determining the suitability of fire clay brick to meet a variety of service conditions."

3. "Deformation is not apt to be an important cause for failure of fire clay brick in a furnace wall and will occur only when a high temperature is developed at a considerable depth in the wall."

This conclusion will explain the reason for cupola lining failures where a cupola is operated for long periods with a heavy lining—that is a cupola "lined down" for decreased capacity. Under such conditions the brick becomes heated more uniformly

than where they occur as a single layer against the shell with the result that the fluxing action within the brick takes place over a greater area than the exposed face of the brick, resulting in deformation of the brick.

The question of insulating the melting zone has been raised on several occasions. It can be seen from the above statements that any attempt at preventing radiation through the lining will result disastrously for the lining. It would appear that a much better method of heat conservation would be in the direction of utilizing the heat passing up the stack, because chances for success would certainly be greater due to higher radiation there than exists at the shell of the melting zone.

Spalling

No doubt the greatest single cause for cupola lining failure is the result of spalling. Spalling is caused usually by sudden changes in temperature, although the amount of destruction resulting is governed very largely by the texture of the brick. This condition, therefore, goes back to the manufacture of brick. It is generally supposed the bricks made of finely ground clays are more liable to split on alternate heating and cooling than those made of coarse grained material. In the latter type, the strain is relieved by the fissures existing between the larger grains, which, as a rule, are not so continuous as in the finer grained material, thereby preventing a distinct cleavage line. Spalling of brick results from the inability of the brick particles to move freely during relatively sudden temperature changes.

In the cupola, spalling will be greatest in the vicinity of the tuyeres, due to the entrance of air at room temperatures impinging upon the hotest part of the lining. The directions of the air currents are continually changing because of the shifting of the particles of the charge as well as the metal and slag streams.

The application of daubing mixtures to cupola linings also has an effect upon spalling. In practice it is common to wet the lining thoroughly in order to cause the daubing to stick—there seems to be no alternative to this practice, yet it leads to distressing results unless properly handled. When the cupola is rapidly heated before allowing the daubing to dry out completely, steam is gen-

erated between the lining and the daubing, which causes the latter material to become dislodged, with the result that the lining is left unprotected in the places where the daubing has been chipped off. This condition gives rise to a further difficulty in that the daubing once laid open through broken patches is weakened and susceptible to abrasion, particularly at the upper part of the melting zone.

Daubing often cracks and falls out upon drying, due to the shrinkage occasioned by the loss of the moisture in the original mixture. This condition can be prevented in a large degree by noting particularly the character of the fire clay forming the base of the daubing mixture. In the case of fat clays it is well to use a large proportion of grog in the daubing mixture. A most satisfactory grog can be made by grinding wornout fire brick to about a 12 mesh and mixing with only enough fire clay and water to give the desired bond.

In the preparation of the daubing mixture, care must be given to the selection of the materials used. The fire clay should be of equal quality to the brick and nothing but highly siliceous sand should be employed. The grog should likewise be ground only from fire brick of accepted quality. Dr. Moldenke in "The Principles of Iron Founding" so pointedly remarks about the folly of using local clays in daubing mixtures, yet the writer encountered one cupola in which building sand was employed in addition to the type of clay mentioned above. In this installation the owner complained about excessive slags and short lived linings, both of which were to be expected under the circumstances.

The idea of using common salt (NaCl) as a wash over the daubing mixture has been suggested as a means of forming a glaze over the lining with the idea of increasing the refractoriness as well as the resistance to abrasion. Undoubtedly the practice of using salt for the glazing of ware is successful, yet in a cupola lining a different set of conditions must be confronted. At the elevated temperatures encountered in the cupola lining the salt may volatilize and produce a vapor which when it is condensed will have a corrosive action on the refractory lining by increasing its fusibility.

There is, no doubt, excellent opportunity of increasing the utility of the daubing mixture by the addition of highly refractory

materials, preferably of a neutral character. The writer used a heavy coating of carbonaceous material over the daubing mixture during a trial heat in the cupola in the Engineering Shops at the University of Washington. While the results of a single test are far from conclusive it would appear that improved lining conditions resulted. This experiment was tried mainly as a means of combating fluxing or slag action.

Slag Corrosion

The reason for lining failures in the melting zone can be traced in a large measure to the corrosive action of the slag. This is readily apparent when the acid nature of fire clay brick is considered at elevated temperatures, keeping in mind the basic nature of the lime slag. Theoretically, this reaction between an acid and a base should result in the formation of a salt—yet in a cupola the reaction is not so simple, there being other fluxing agents present which add to the complexity of the entire situation. One of these, Fe_2O_3, has been studied by A. H. Kuechler in an article* showing clearly that iron oxide is a potent flux which tends to lower the deformation period of fire clay refractories. The complex and variable nature of cupola slags makes a detailed study of their corrosive action a difficult subject. Hirsch has found that cupola slags penetrate fire brick chiefly through mechanical action, yet Portland cement has a corrosive action tending to dissolve silica and alumina to form new compounds. The presence of lime (CaO) in fire clay has a known effect upon the reduction of the fusion point of the resulting brick. Alkalies vaporize at operating temperatures and are detrimental to fire clay brick upon condensation of the vapor, according to Searle.

The corrosive effect of slags is also governed by the manner in which the lining is originally laid—large or wide joints permit relatively easy penetration, a condition which is accelerated through the use of inferior clays for lining mortar. A good general rule to follow in this connection would be to use the same kind of fire clay for the mortar that is employed in the manufacture of the brick. In preparing the mortar, it would be well to follow the suggestions outlined under the preparation of the daubing mixture.

*Journal American Ceramic Society, vol. 9, No. 2, Feb., 1926.

The nature of the brick or cupola blocks used in the lining must also be considered. If they are made of coarse material resulting in considerable porosity slag penetration is more rapid than where a dense, compact surface is encountered. On the other hand, if the materials are of fine texture and the slag particles are finely divided also, rapid corrosion is bound to result. It would appear, then, that a cupola brick to withstand slag corrosion should be provided with a firm exterior. This result can be obtained in the manufacture of the brick by the pressure exerted upon them, forcing clay laden water particles to the surface. The importance of a proper surface readily shows up when the lining is picked out, injuring the vitreous surface of the brick; under such circumstances careful daubing is the remedy. The production of a well vitrified surface is also a function of the burning process. Some manufacturers burn the best grades of fire brick twice to produce the desired results. A. Reynolds has an English patent covering a method of increasing the resistance of a brick to corrosion by subjecting the working face of the ware after its first firing to a temperature sufficiently high to produce incipient fusion. The bricks are embedded in the floor of a furnace with their working surface exposed, the spaces between the brick are filled with some highly refractory material such as carbon, etc. The furnace is then heated to produce the desired effect upon the brick.

There are still other sources of slag corrosion which may affect the refractoriness of brick in the cupola. Among these may be mentioned the possibility of sulphur being changed to sulphuric acid (H_2SO_4) whenever moisture is encountered in the fuel. Then, too, the ash content of the slag should not be overlooked. In summing up the reasons for slag action, the presence of lime and alkalies, two potent fluxing agencies, are undoubtedly the main accountable elements.

Cupola linings, unlike many types of metallurgical furnaces, are subjected to deterioration by the abrasive action of the descending charges. This source of failure must be considered from the melting zone to the charging door. The problem presented is not as acute as the one afforded at the melting zone—yet the proper selection of lining material must be considered.

A close, hard, well burned surface on a brick offers the highest resistance to abrasion—this is, in fact, the same type of brick that offers highest slag resistance.

Other elements tending to destroy cupola linings are the cutting action of flames, also the chemical reactions set up through operating both under reducing and oxidation conditions. While the former condition is to be expected, the latter often may be encountered.

The employment of monolithic linings in cupola furnaces appears to be gaining in popularity. There are many attractive features connected with this plan and its broader adoption is being staid more or less through the old idea that a radical departure from standard practice must be subjected to a thorough probation period. Monolithic linings in boiler furnaces are quite common in this section, although the same thing cannot be said of cupolas. The writer recently had a very satisfactory experience in using a kaolin monolithic lining. This lining was rammed into place—yet it would seem that the adaption of a cement gun for this purpose would give even better results. Particular care in "burning in" had to be given in the case of kaolin because of its highly refractory character. The use of this material in the breast proved a failure for the reason already assigned.

In conclusion, it might be well to mention a word in regard to other possible refractory materials for cupola linings. A study of the equilibrium diagram of the alumina—silica system as prepared by Bowen & Greig of the Geophysical Laboratory will prove of unusual interest. Kaolin (46 per cent Al_2O_3), sillimite (62 per cent Al_2O_3), and mullite (71 per cent Al_2O_3), are materials that would lend themselves very favorably to cupola linings—yet they offer the same objection as the so-called "super-refractories" in that the first cost is so high as to discourage their adoption in place of the usual type of fire clay brick or cupola blocks.

Discussion

J. T. MacKenzie: The author has brought out very well the fact that the daubing clays that a lot of us use are not at all suited for that function. Some years ago we quit the yellow clay in the cupola and we were very much surprised to find that the bridging practice ceased. In fact, last week I ran a cupola at 2,800 degrees Fahr. for 31½ hours and when it dropped

there was not six inches of bridge anywhere around the tuyers, and you will find that the bridge that you have been thinking was on account of the natural freezing up of the coke and slag in front of the tuyers is about two-thirds due to the melting away of your grog.

The statement, though, that Mr. Schaller made about the lime and alkalis being the two main accountable elements, I can't agree with. Of course, we all know that the reaction between alkalis and silica will go on at that temperature very vigorously, but as a matter of practical fact, if you thin your slag up to the right point, you get the least corroding slag on the cupola lining. If you are running a stiff, sticky, highly ferruginous slag, you have the worst possible condition on the cupola lining. Now, you can actually add lime to that, possibly one or two per cent more of your iron charge, and cut the corrosion in half or a third, and the same way with the alkaline fluxes, such as fused soda ash that is such a quick medicine for slag. You can really reduce corrosion, if that is what you need, by thinning the slag, because the main point is to get it out of there.

And I would also say that our experience is that abrasive corrosion, which is intimately concerned with spalling in the upper part of the stack, is a point we have to consider. We never reline a cupola on account of the melting zone, haven't done it for five years. What we have to reline a cupola for is the abrasion up above the melting zone, that is the point that you can't patch. They speak of monolithic linings, but they are no good up there, because you can't get enough temperature to burn them in. All refractory material must be burned before it has any mechanical strength. Now, if you have a hard, abrasion-resisting brick up there and never get any slag on it and never put any water on it, it probably would be the best brick to use up in there, but as a matter of fact, when you are blowing out the cupola, you spit hot, molten slag against those brick, then you pour water on them, that breaks that shell and when the first piece of iron hits it, it is gone. That doesn't amount to much the first day and it doesn't amount to much the second day, but when you are running the cupola like we do, we have just taken out some stacks that were put in February 1, 1926, and the sum total of those small chips caused by the action of the hot slag on the brick is really what has destroyed that lining. Our lining is just as thick now in the melting zone as it was when we started.

C. S. SCHALLER: I am very appreciative of Mr. MacKenzie's criticisms. The statement I made in my paper is misleading. I state here that "In summing up the reasons for slag action, the presence of lime and alkalies, two potent fluxing agencies, are undoubtedly the main accountable elements." What I had reference to there is the type of fire clay brick that I know in our country, and those are brick that are made from local deposits, and the presence of alkalies in clay and high lime content have caused, if I may use the expression, the presentation on the market of fire clay brick which are really not suitable for cupolas. And I might say the thing that led me to study this subject was the fact that some two years ago I was called

to observe a cupola in Tacoma where I found that they were relining the melting zone as often as every other day, and that set me to wondering what the trouble was.

Now, what I have attempted to do here is to point out the different causes of failure, and if you read the paper, you will notice that the thing that will ameliorate one condition helps to accentuate another, so it is really a question of balancing one against the other to meet the local and individual conditions.

G. S. EVANS: I was very much interested in the paper. On the matter of corrosion in the cupola I think we know far too little. I am interested in developing the use of alkalies in foundries and, naturally, I am interested in that phase of it. We have boiled alkalis in the cupola with nothing else and were surprised to see that you would not have the cutting action that you would expect. We have tried in cupola practice using a certain California product, which is supposed to be very highly basic and should not be attacked by basic slags, but as a matter of fact in the cupola the linings of that nature will not stand up with an ordinary cheap brick, although chemically it ought to stand perfectly. This basic brick will not stand in molten iron. From your experience in foundry practice I believe all of you will agree that the hard, dense, second-quality fire brick, as they are known, from a refractory standpoint give the best service. I had quite a lot of experience when I was operating twenty cupolas for the Griffin Wheel Company and we had various plants all over the country, and we were buying the best brick we could buy, but, incidentally, in a certain place at one time we got hold of a brick, about the cheapest quality fire brick that we could get, and that today is used in all of our plants.

J. MURPHY: Mr. Chairman, I think there are a good many in this audience heard as well as I did the statement of Mr. MacKenzie. I think he stated there was no appreciable burning out in the melting zone of his cupola in six months' continuous operation. If I understood you right, Mr. MacKenzie, you said about six months' continuous melting gave you no appreciable wear in the melting zone of the cupola.

J. T. MACKENZIE: We daub every day, of course; I mean that we hold it. We have had no trouble in replacing the brick.

MR. BRANT: I would like to ask Mr. MacKenzie if he is using exactly the same material in daubing that he has rammed into his lining.

J. T. MACKENZIE: Well, we have put in a lining with a 3-inch offset, we use a 12-inch block above the tuyeres, one row, and then a 9-inch block up three feet, then resume the 12; and we daub that on the first heat, and the daubing mixture we use is the same thing we daubed the holes with. We use a great many split brick, 2-inch brick, sometimes block, anything to fix the holes.

Correction of Cupola Operation by Means of Cupola Temperature Recorder

By H. W. Dietert,* Detroit, Mich.

The iron temperature recorder as described in the paper[1] presented before this association in 1925 has continued to prove satisfactory for recording the iron temperature. The maintenance and operating care is very small, which makes it a practical shop installation. The United States Radiator Corporation have six of these recorders in operation and find them a great aid in the standardization of cupola operation and iron temperatures.

The cupola temperature recorder consists of three parts, the hood, a thermo-couple and the recorder. In Fig. 1 is shown a section of a cupola spout. The hood consisting of a cast iron frame is shown setting over the spout and supported by means of suitable fingers resting on the iron frame of the spout. The object of the hood is to collect the gases rising from the molten iron stream and also to form a constant temperature compartment for the gas collected.

The electrical thermo-couple with its bare tip responds to variation of temperature of the iron and causes the recorder to make a permanent record of the iron temperature throughout the heat.

Applicable to Either a Continuous or Intermittent Flow of Iron

The cupola recorder may be adapted to either a continuous or intermittent flow of iron from cupola. In adapting the recorder to an intermittent operated cupola, the hood is mounted on the cupola spout as shown in Fig. 1. One brick is left out of the bottom of the spout just beneath the hood to form an iron reservoir as shown in Fig. 1. This reservoir of iron will stay molten for about ten minutes and in this manner the recorder will quickly

*Engineering Dept., United States Radiator Corp.

[1] Dietert, H. W., Iron Temperature Recording, Trans. Amer. Foundrymen's Assoc. vol. 33, pp. 474-487, 1926.

respond to a flow of molten iron when the cupola is tapped. The recorder will normally come to correct reading within 30 seconds when once heated. For continuously operated cupolas it requires on an average 12 minutes for the recorder to come to correct reading at the start of the heat.

The thermo-couple is suspended 2 inches above the iron stream. When a proper hood is used, a variation of plus ⅛-inch from the standard 2 inches will cause the recorder to read 12 degrees low. This is much closer than is required in actual practice. The 2 inches is maintained by lining the spout with the aid of a template and the use of a test wire to occasionally check the

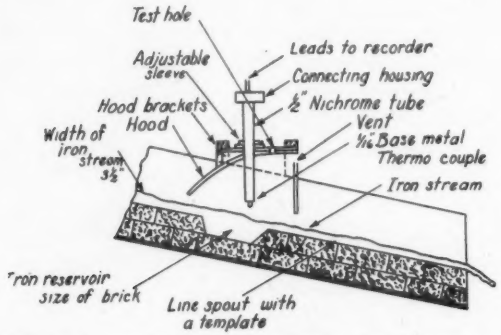

FIG. 1—SECTION OF CUPOLA SPOUT SHOWING ASSEMBLY OF HOOD AND THERMOCOUPLE OVER IRON RESERVOIR FOR AN INTERMITTENT FLOW OF IRON

distance. The life of the thermo-couple is from three to four months, and it is easily and cheaply replaced. A specially designed couple head is used to allow for repairing the couple wire at least three times, thus giving a total life of nine months for one couple wire.

Iron Temperature Charts

A study of the iron temperature charts for cupolas located at the various plants of the United States Radiator Corporation will show some of the typical errors of cupola operation found and also the manner of correcting the cupola operation to give a uniform iron temperature throughout the heat.

A cupola temperature recorder was first used on a hand charged 72-inch cupola located at the WN Plant. In Fig. 2 is shown a typical chart as obtained from this cupola. One may note that the temperature chart has a periodic wave. The average temperature is near 1640, which was found to give very good results. The cause of this wave has not been determined inasmuch as results secured with the iron have been so satisfactory. However, it shows that the cupola has a definite characteristic all of its own, which we have not found at any of the other plants.

A recorder was next installed at Plant D which operates a 72-inch cupola and uses mechanical charging. The first iron temperature chart secured at this plant is shown in Fig. 3. A study of this chart will show that from 12 to 1:30 P. M. the iron fluctuated near 1400. Then at 1:30 P. M. it dropped steadily to 1200 at 2:40 P. M. The temperature then increased suddenly to 1300 and remained at that temperature for the remaining heat. A second sudden rise in temperature may be noted at the extreme end of the heat.

Causes of Irregular Temperatures

The drop in temperature between 1:30 and 2:40 P. M. was remedied by decreasing the amount the bed was burnt. As previously, the bed had been forced for 12 to 15 minutes with the blast on, this was decreased to 10 minutes to avoid overburning the bed. This reduced the drop in temperature at the above mentioned period. It was entirely eliminated by discontinuing the practice of reducing the blast at intervals, which was practiced to avoid excess of iron, during the heat. The sudden rise at 2:40 P. M. was caused by a sudden opening of the blast gate to obtain the maximum output of the cupola. The jump in temperature at the extreme end of the heat was eliminated by reducing the blast at the end of the heat as the iron level went down in the cupola.

The cupola operation as described seems very uncalled for; however, not until one has a picture drawn of his cupola operation by a recorder can he feel safe that he himself is not doing many tricks that would cause the recorder to show a very peculiar shape chart in place of the straight line chart which is so desirable.

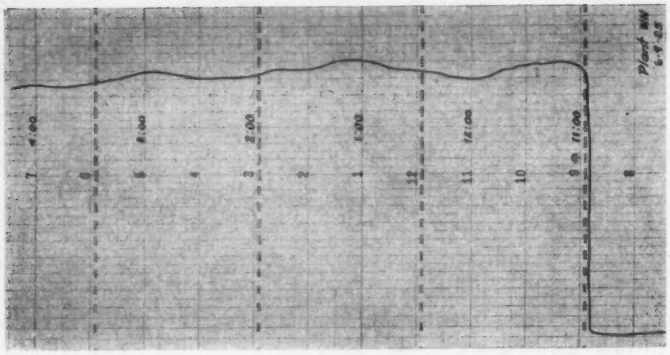

FIG. 2—TEMPERATURE CHART SHOWING PERIODIC FLUCTUATIONS OF TEMPERATURE

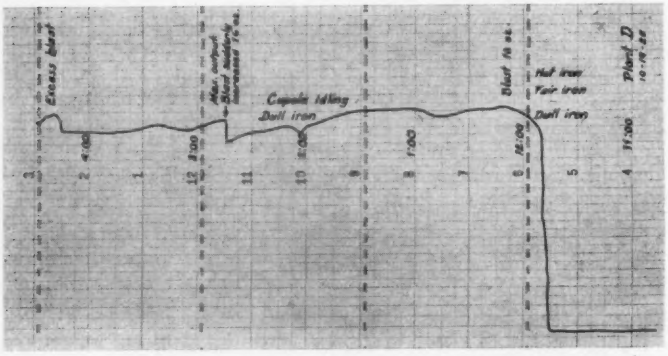

FIG. 3—TYPICAL TEMPERATURE CHART OBTAINED WHEN RECORDER WAS FIRST INSTALLED AT PLANT D

After the operation of the cupola at Plant D was changed to conform to changes enumerated above, temperature charts were obtained as shown in Fig. 4. The upper line of the chart shown in Fig. 4 shows the iron temperature, while the lower line shows the blast, in ounces when multiplied by 2. The importance of volume of air is recognized, but due to appreciation of simplicity, the recorder was equipped with a pressure recorder. A recorder

is now designed to register air volume, stack temperature and iron temperature.

Use on Hand Charged Cupola

A third recorder was installed at Plant G on a 60-inch cupola which is hand charged. The first chart secured from the cupola was identical to the chart shown in Fig. 5. A good description may be given by following the cupola operation in proper order. The bed was lighted with an oil torch at 12:10 P. M. The cupola spout was dried out from 12:10 until 1:00 P. M. The blast of

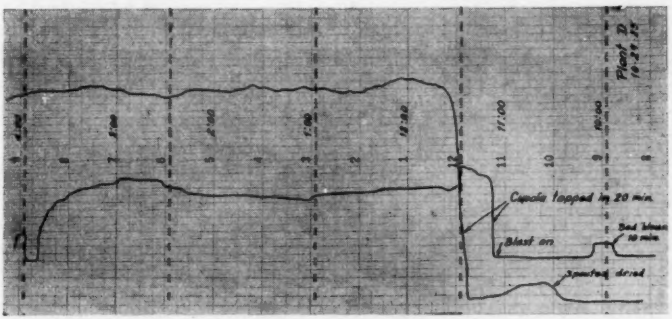

FIG. 4—TEMPERATURE CHART SECURED BY CORRECTED CUPOLA OPERATION AT PLANT D

15 ounces was put on at 1:00 P. M. and the first iron came out in 17 minutes. Iron came over the skimmer spout in 24 minutes. The temperature of the first iron was 1400 and stayed there until 2:10 P. M., when it rose to 1500 range. At the end of the heat the blast was not reduced, this resulting in an excess of air and the iron was highly superheated but lifeless.

In Fig. 6 is shown the chart secured after the bed was burnt more thoroughly, last coke charges cut less and blast reduced after finishing charging. One may readily note how the temperature of the iron may be maintained at the desired range by altering the cupola operations. The timed operations of the cupola are as follows: Spout heated at 11:45 A M., bed blown 4 minutes, blast

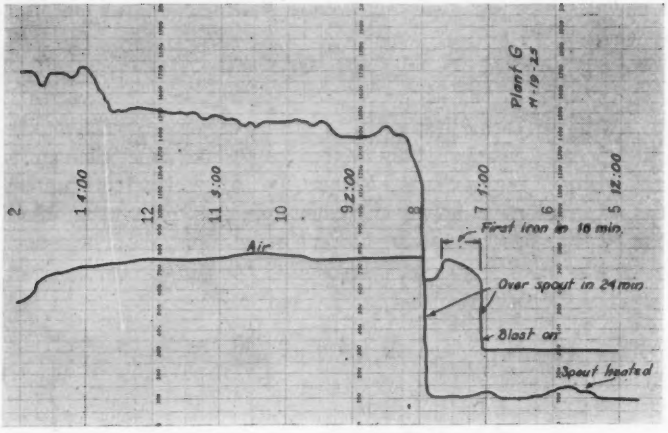

FIG. 5—TYPICAL TEMPERATURE CHART OBTAINED MAKING CHANGES IN CUPOLA OPERATION AT PLANT G

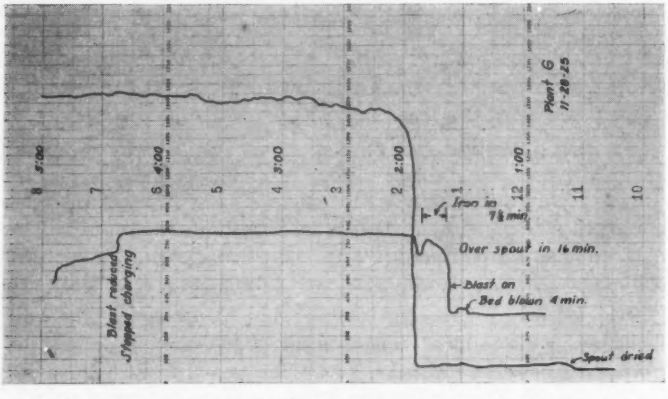

FIG. 6—CORRECTED CUPOLA OPERATION TO SECURE UNIFORM IRON TEMPERATURE AT PLANT G

on 12:43 P. M., first iron in 8½ minutes, iron over the spout in 16 minutes and blast reduced 7 minutes after final charging. The volume of air during heat was maintained at 7200, giving an output of 12 ton.

Results of a Low Coke Bed

The result of operating a cupola with a low bed is clearly shown by the temperature chart, Fig. 7. A very irregular temperature curve is secured, showing that the iron reaches at times a very high degree of superheat. The iron, in short, is bessemerized as the result of melting it in a blast of raw air. The iron temperature fluctuates up and down due to the fact that the melting zone raises and falls near the tuyeres. A temperature chart of this kind is accompanied by castings with gas blows and kindred losses with

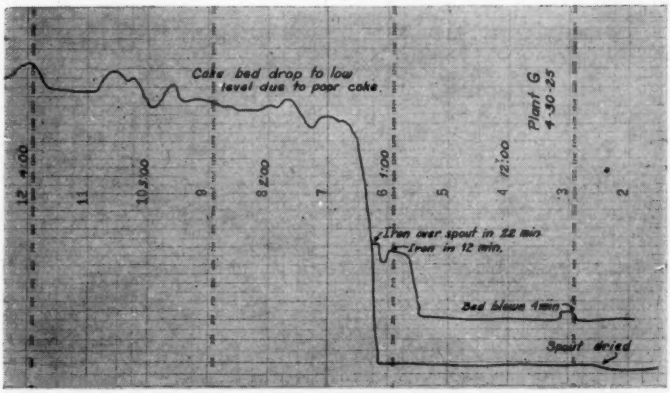

FIG. 7—EFFECT OF A LOW COKE BED

lifeless iron. When a foundryman sees iron of this kind he terms it as dull, dirty coated or scummy iron. When considering temperature only, it has a high temperature but is of a very poor physical quality. As seen by a foundryman's eye it is dull, for it acts as dull iron. A foundryman can tell iron in terms as good or bad; but it seems that there are chances of one being misled when he believes he judges iron by temperature only. The foundryman's eye judges iron by a combination of temperature and physical properties.

The cupola recorder measures temperature only and the charts as shown herein are 1000 degrees lower than actual temperature

of the iron. The reading of the recorder is an arbitrary one and is of use only when one determines by actual practice what reading of the recorder will give him best results. An iron between 1300 and 1400 will give coldshuts, between 1500 and 1600 it is properly melted for those desiring a hot iron, while an iron that will read 1800 is what one might say is too hot and most likely abused.

Effects of Booster Charge of Coke

Frequently, we hear of someone referring to the effect of a booster charge of coke. The effect of a 200-pound booster coke

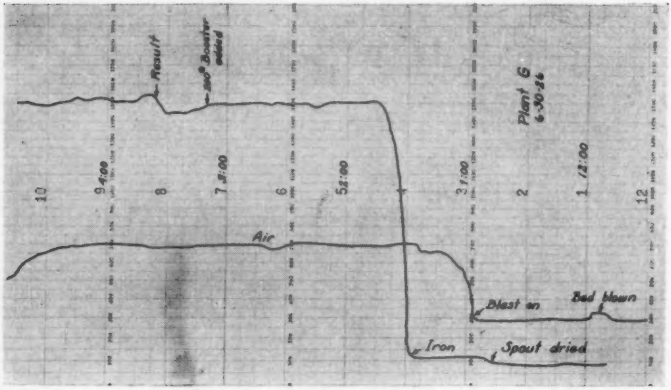

FIG. 8—INCREASING TEMPERATURES BY ADDING A BOOSTER CHARGE OF COKE

charge in a 60-inch cupola is shown by the temperature chart, Fig. 8. The iron temperature was running at 1500 from the start of the heat until 3:08 P. M. Then at 3:08 P. M. the temperature started to drop. In order to arrest this temperature drop a booster coke charge of 200 pounds in addition to the regular charge was placed in the cupola, at 3:10 P. M. The temperature continued to drop until 3:37 P. M., at which time the booster reached the melting zone and took effect. The temperature rose immediately from 1440 to 1500. This shows one means of increasing iron temperature during the heat.

Checks Standard Practice

A number of the plants did not find it necessary to change their cupola operation to give a straight line temperature chart. These plants find the cupola recorder a valuable instrument to continually check their cupola operations as it will immediately show any deviation from standard practice. The cupola recorder is very valuable to the foundry in that it settles the age old question whether we had a streak of dull iron in yesterday's heat or were the castings lost due to inefficient handling of iron in transportation or in bad pouring.

Conclusions

1—An overburnt coke charge will show up as a drop in the iron temperature after about three-quarters of an hour of operation.

2—An underburnt coke bed will cause the first iron to come at a low temperature for as much as 30 minutes, depending on how underburnt the coke bed was.

3—The idling of a cupola either by reducing the blast or by closing the blast entirely will decrease the iron temperature.

4—An excessive reduction of the coke bed or coke charge will produce a very irregular temperature line.

5—A booster coke charge during the heat will increase the iron temperature when the booster reaches the melting zone.

6—When charging is stopped and charges in cupola go down the air blast must be decreased for pressure blowers to give a uniform temperature at the end of the heat.

7—A comparison of the volume meter reading and the temperature chart reading proves that correct air volume is required to secure desired temperatures.

8—A comparison of temperature charts between hand and mechanical charged cupolas indicates that mechanically charged cupolas will give greater uniformity of temperature over an extended period than a hand charged cupola.

9—When insufficient coke is charged the temperature will raise and lower for each charge melted. There is no exact optimum coke charge which may be applied to all cupolas. The optimum coke charge is dependent upon the quality of coke, design of cupola, charging methods, size of pigs and scrap charged and the desired temperature of the iron.

10—A low coke bed, or a coke bed that has burnt to a low level, will show up on the temperature chart as a sudden jump of at least 100 degrees.

11—Where each iron and coke charge are not weighed a greater coke charge must be used to secure a uniform temperature to allow for fluctuations in charging.

12—A uniform temperature chart requires a uniform melting zone. Whenever the melting zone changes a change is immediately noted on the chart. The quality of the iron will also change.

Discussion

C. A. Roberts: We installed a pyrometer control some thirty days ago and we now wouldn't be without it, because of the information it gives us. We know that as soon as our temperature goes down, although the temperature indicated is only relative, below a certain point we see the results in our loss.

I would like to ask the author whether he uses a variable speed motor on his blower or not.

H. W. Dietert: No, we don't use a variable speed motor. On the Roots Blower and on the General Electric we control the intake, and on another blower of a different type we have control by a gate between the blower and the cupola to get our air volumes we try to work as close as we can to our designated air volumes.

C. A. Roberts: One of our troubles with slagging at the front of the cupola is that the slag every once in a while gathers on the point of the thermocouples.

H. W. Dietert: I suggest putting in just a partial skimmer block there to keep that slag away from the thermocouple.

H. M. Lane: Out at the Maytag Plant we put in Green blowers, directly driven by variable speed motors. We can get absolute control.

When I was out there a little while ago the man in charge of melting said, "I want to show you something." He went up on the cupola floor

and took the biggest chunk of coke he could find. We then stopped at the pyrometers and looked at them. They have a little mezzanine floor almost immediately above the spouts and they have optical pyrometers trained directly on the spout and in that way they get very accurate results. We weighed the piece of coke. It weighed about ten pounds. We broke it up and scattered it around on the charge and in a few minutes up went the temperature ten degrees, just from the effect of a piece of coke like that. The operator can lower or raise the temperature exactly as he chooses, because he can control his blast. He has an instrument for indicating volume and pressure of the blast.

A. E. HAGEBOECK: Mr. Dietert, I would like to ask a question in reference to the statement you made about putting in a large piece of scrap. At our plant we use a 2-wheel cart for bringing up the charges and invariably the man who is bringing up the charge will get a big slab or something and put it on the side of the cart, it makes a nice container for the rest of the charge. The rule is that he should break it up before he puts it in the cupola. Well, you know how it is, rules are rules, but they are not always followed. I would like to ask Mr. Dietert if he has any standard for scrap size for his 60-inch cupola.

H. W. DIETERT: Yes. We have what we call our scrap specifications, not to exceed 24 inches in length or 6 inches in diameter.

A. E. HAGEBOECK: Yes, but would you put a piece, say, around 24 inches in diameter in the cupola?

H. W. DIETERT: No, for you can judge from this test that it would give you at least 100 degrees or more drop if you happened to be on the danger line. I would never put that in; I don't think it is going to melt at the right place; neither is it going to mix with the rest of the iron.

A. E. HAGEBOECK: How small had it ought to be?

H. W. DIETERT: It would depend on the size of cupola.

A. E. HAGEBOECK: Suppose you have a run-out piece that came back from the foundry, some two feet in diameter.

H. W. DIETERT: That would divert your blast, wouldn't it? I don't know how in the world you would definitely decide what to reject. This scrap piece I mentioned was rather unique. The cupola attendant at the plant at Dunkirk said he was going to find out whether that recorder was good or not. He knew how to test it, and that was his test, to poke in a big piece of scrap, it wasn't necessarily large, put it in and wait to see that little kink on the curve. Then he said it was all right, that is all he cared about.

C. A. ROBERTS: We have made it a rule that we will not allow anything over eighty pounds to go in our cupola of 72 inches diameter. Furthermore, our 30-inch radiator sections we have broken in half because we found out when they went in in long sections and stuck up on end, it opened the whole charge. We use a mechanical charger. We break up our sections and don't allow a piece over eighty pounds to go in there.

R. D. CARVER: In one of our General Electric Co. plants our Mr. Bell started us off in trying to find out the effect of moisture on the blast. Of course, on a rainy day the melter, the foundryman, will tell you that he gets a better melt than he does on a hot dry day. We found there was a little effect but not enough to make much difference. But we couldn't very well measure the volume and get it very accurate. We considered the Pitot tube, but didn't think it was worth while to try it.

At our River Works we started in to try to get the volume of the air. We used a Venturi meter on the outside and checked up the temperature of the metal and the pressure. From there we went to find out the relation between the current delivered to the motor and the volume of air, and we found that atmospheric conditions being the same and the temperature and everything else, the cubic feet of air delivered by the motor was proportional to the amperes of current delivered to the motor, assuming that the power factor and the voltage was constant.

Well, we got some mighty good results that way. And then, to go further, we wanted to eliminate the atmospheric conditions, so we went to pounds of air instead of cubic feet. Then, to go further, instead of dealing with the amperes, which will vary with the voltage and the power factor, we went to a polyphase wattmeter, so, therefore, we found that the volume delivered to the cupola by the blower, or the centrifugal blower, is directly proportional to the power delivered to the motor. At our River Works we have a polyphase wattmeter at the spout and another one at the control to the motor, so that at any time we can vary the two of them.

At the other plants I think they have gone one step further and they have actually put a control to the blast gate, which is motorized, and the control is at the spout, so the spout tender can control his blast immediately from the spout, just as soon as he sees that there is any variation to the power input to the motor, which is graduated in pounds of air per minute.

This will probably mean another step, that we will automatically control the pounds of air delivered to the cupola by motorizing the blast gate with the polyphase wattmeter.

I thought possibly you would be interested in another development we have going on there at the River Works. You have all heard, no doubt, about the fused quartz they have been making at the River Works, and they have developed a special thermocouple. This thermocouple has been run up to 2,300 degrees Cent., which is very hot. We don't very often run into it, but it has been actually taken up to 2,300 degrees Cent. for over 100 times in a gas furnace and is showing no deterioration.

As far as the iron foundry is concerned, I have tried quite a few times to get the temperature of the iron as it comes from the spout. I can actually get the temperature, which has been between 1,400 and 1,500 degrees Cent. of the metal in the ladle, but have been having some difficulty with the sheath on the couple. We are cutting down the diameter of the sheath and within the next couple of months we hope to be able to put on a recording instrument and get the actual temperature of the metal.

In our Everett open-hearth furnace we have one of these thermocouples in the roof and we have had it there for ten weeks and it shows no deterioration whatsoever. We had to make two or three installations in order to get it working right, but we have more equipment coming so we can automatically record the temperature of the roof of the open-hearth. In one of our brass foundries we are putting in this week an installation whereby we can automatically control the temperature of the brass furnace.

C. A. ROBERTS: I don't think anybody who uses a pyrometer claims that you get anything exact by it, but it does do this, and we have proved it, that it gives us an absolute check of what the cupola is doing. In other words, there is always an argument in the foundry as to whether the iron is too hot or too cold, and we know by the variation of this pyrometer that if we go below a certain point, we are bound to lose this eighth metal line loop casting. The day that our iron goes below a certain definite point, the next day we find we have had a lot of cold shots and miss runs and a lot of other things that we can trace to the operation of the cupola. So all we really claim for it is that it keeps everybody on their toes. In other words, it tells tales on them; if they don't do the job right, it tells on them automatically. That is all we claim for it, is that we have practically eliminated cold shots in our castings by the use of it.

R. B. SCHAAL: Mr. Dietert's work is certainly very excellent and its chief value does lie, as has been mentioned, in keeping the men who operate the cupola on their toes in seeing that things are not neglected. There is no difficulty if we have someone standing there who knows, or can tell by observing the temperature of the iron as it flows over the spout, what is happening in that cupola, but that takes a valuable man's time just to stand there. This, in other words, is a labor-saving device as well. If we intend to control the cupola operation closely, someone must do that control work. This instrument will help in eliminating a lot of expensive supervision, and that, of course, is what we are all after.

J. T. MACKENZIE: Mr. Dietert said that the men in the shop talk of 1,400 and 1,500 and 1,600 iron. We have found that that is true with the optical pyrometer, that if it had done nothing in the world but give the men a scale by which to talk temperatures, you could well afford to have bought a dozen of the things. Around our shop we use the L. & N. optical pyrometer and nobody ever hears of degrees, 1,400 or 1,500, they all talk milliamps. If you ask a man how hot the iron is, he tells you 468. You can go get your pyrometer and read it if you want to, but he will be within two points.

There is one criticism I would like to offer on Mr. Dietert's paper and that is that he didn't give us any tie-in with the optical pyrometer. It seems that that is a very general application now, in fact, it was considered of sufficient importance to spend a good deal of the Association's money in checking up on, and if Mr. Dietert would be so kind as to put in the Transactions a chart or two with optical pyrometer readings at peak points,

or, if there are no peaks, so much the better, I think we would appreciate it very much.

H. W. DIETERT: Mr. Chairman, we have those curves and will supply a set of comparative curves. We have plotted our pyrometer readings on the same chart with the instrument readings and they agree very closely.

MR. DRACO: Mr. Dietert, what difference do you notice in the regularity of your temperature curve between hand charged and mechanically charged cupolas?

H. W. DIETERT: From day to day we can get it more uniform with the mechanical charger. We save a little more coke by using the hand charged method, because the hand charge is a little more dense than the mechanical, but we do have more uniform iron out of the mechanically charged cupolas, with one exception, on a cupola where the hand charging is a hobby with the operators and they are out to beat the record of the mechanically charged cupolas.

MR. DRACO: What mechanical charging device is that, the side dump?

H. W. DIETERT: The bottom dump.

CHAIRMAN L. L. ANTHES: Well, this paper of Mr. Dietert's has been very entertaining and constructive. It is just such things as we want, we want something that will open up an argument. The majority of you know, all being practical foundrymen, that we want to be able to control the different elements contributary to our output. We want to control our cupola melting, our coke, we want to control our iron and our sand. We have certain standards to work by, but, unfortunately, many of these standards are not observed. As Mr. Hageboeck said a little while ago, rules are rules, but what good are rules unless the rules are enforced? And that is one of the greatest weaknesses in the foundry business. Now, the steel people have given the foundry people, the cast iron and gray iron people, a pretty good run, and they led for a number of years, but we think we are going to catch up to the steel people through our Research Committee.

Test Bars to Establish the Fluidity Qualities of Cast Iron*

By C. Curry, Ardennes, France

Among the most interesting problems which regular foundry practice brings up, the fluidity quality of the metal is among the ones that deserve quite particular attention. If, in fact, the quality of the metal is one of the fundamental ones in foundry work, the search for practical means that will aid in reducing the percentage of scrap castings seems no less interesting.

What Is Fluidity?

We will accordingly define the fluidity or running qualities (life) as follows: *The aptitude of a liquid in a given condition to fill a mold prepared under determined conditions.* This quality depends on a good many factors such as temperature, viscosity of liquid, nature of liquid, temperature of mold, weight, surface, superficial curvature of the castings, nature, dimensions and dispositions of the mold, conditions of surface, etc.

The knowledge of only one of these factors does not permit us by any means to determine the quality which we want to define. Thus for instance; the temperature of an alloy is only an insufficient indication for the foundryman; iron coming from a cupola may have a very high temperature and still possibly is not as liquid as another one having a lower temperature, but being of a different chemical composition. Accordingly it is of the highest importance for the foundryman to possess a simple and speedy means of investigating, that will permit him to judge promptly on this point which is interesting to him.

Early Investigation

The Higher Foundry School[1] could not but feel interested in this problem, so this research was indicated to the students as

*Exchange paper of the Association Technique de Fonderie de France.

[1] Ecole Superieure de Fonderie, Paris.

likely to form the object of the personal work imposed on each of them, on account of its possibility of being treated scientifically. The result is the present experimental work, performed with the aid of suggestions given by Mr. E. Ronceray, manager of the study course of the Higher School of Foundry Work and augmented by the result of the researches followed since then, which we intend to review in the following portions of this paper.

This problem, moreover, has for a long time constituted the object of intense work of eminent practical men. It seems that the first researches on the subject must be attributed to Thomas D. West, who, in 1898, made experiments as to running qualities by making up the test bar shown in Fig. 1. This test bar constitutes a first attempt, insufficiently handled, still sufficiently interesting, especially if we consider the date when it was performed.

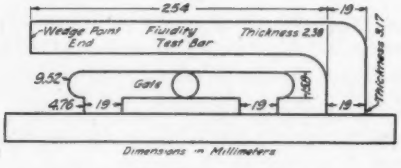

FIG. 1—TEST BAR OF T. D. WEST

The question was studied after West by several persons, and there can be mentioned the test bar of Mr. Ledebut (1904); which test bar of 250x25x1.5 millimeters (9.83x.98x.059 inches) was run on one end which resembles a good deal the foregoing one.

The experiments of A. H. Sexton and J. S. G. Primrose (1911) were made with a thin test bar of the same kind of section (1 inch by 1/16 inch) run also on one end.

In 1917 Dr. Richard Moldenke used a test bar in wedge shape, pointed at one end and of a section of 1 inch x 1½ inches at the other.

It should also be noted that the shops of Brousseval pre-

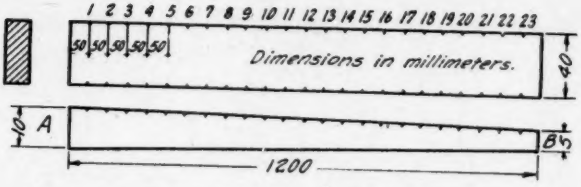

FIG. 2—TEST BAR OF BROUSSEVAL SHOPS

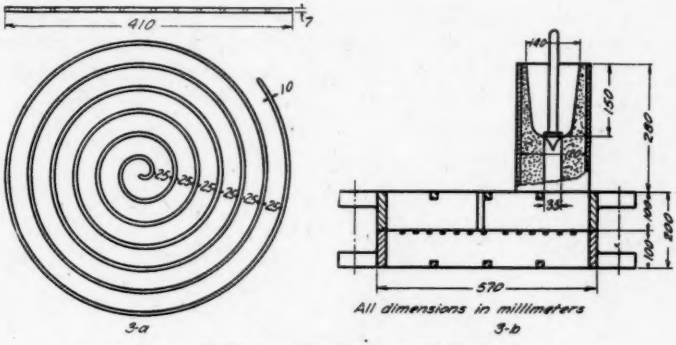

FIG. 3—TEST BAR OF SAITO AND HAYASHI

sented to the first International Foundrymen's Congress in 1923 a similar but very long test bar which is run flat (Fig. 2).

In 1919, two Japanese experimenters, Daikichi Saito and Kennosuke Hayashi[2] originated a test bar of the following form:

"Instead of using a simple, straight rod as a pattern for making the mold, they used a spiral of the type shown in Fig. 3 respectively, in order to show up in a still more striking way the differences in fluidity between samples of different metals. The mold was provided with a pouring gate, and a riser at the center. The pattern was embedded in sand so as to make a mold into which the metal could run."[3]

[2] Proceedings of the College of Engineering, Kyoto Imperial University, II, 83, 1919, and IV, 165, 1924.

[3] *Fluidity of Cast Iron*, a paper presented by Prof. C. H. Desch, at the Sheffield Branch of the Institute of British Foundrymen on Dec. 3, 1921, and published by the Foundry Trade Journal on Feb. 2, 1922.

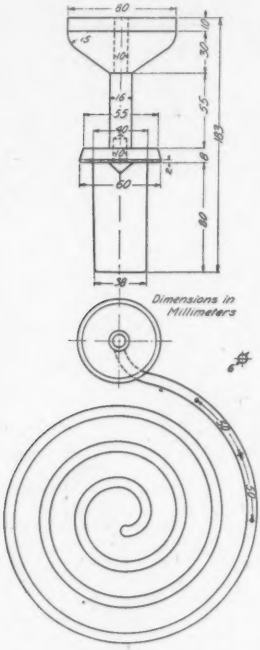

FIG. 4—REMY TEST BAR OF 1922

In 1922, Mr. Remy, malleable founder at Liege, Belgium, again took up this test bar, which he made in the following manner:

The spiral has a circular section of 6 millimeters, or .237 inches. The metal is poured in a basin placed on the side of the mold and runs into a reservoir located underneath where the cast iron runs down, through a hole of 5 millimeters (.197 inches) diameter. The dimensions of the reservoir are established in such a way that the metal penetrates into the spiral only after the filling of the inlet basin and consequently with a speed that is constant. (Fig. 4.)

This test bar has seemed to us at the moment of our writing to embody the most rational conception that has been

reached; hence we have started from this with the intention of examining more especially the influence of the mold itself and of its conditions on the results obtained.

Modified Test Bar

In accordance with Mr. Remy and on the suggestion of Mr. Ronceray it seemed to us useful to modify the section of the spirals which presented difficulties of molding, and to replace it by a section of triangular form with slight rounding at the parting. The dimensions have been calculated in such a way that the new section is essentially equal to the old one in order to observe the same volume of delivery. (Fig. 5.)

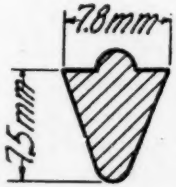

FIG. 5—SECTION OF MODIFIED SPIRAL SHAPE

The first tests run on identical molds, which were rammed by a pressure molding machine, using the same sand and poured as green sand molds in a horizontal position, and poured from the same ladle of hot iron, have disclosed rather noticeable differences in the length of the test bars obtained, and accordingly we had to conclude that the test bar was imperfect.

Successfully eliminating the different factors which seemed to us of a nature leading to errors in the results, we have been able to state that the least burr (fin) in the gate of the core, which gate has a diameter of only 5 millimeters (0.197 inches) and even simply a slight dropping of the sand from this core at the moment of casting, had the effect of considerably modifying the results. We have found that for a gate section reduced from

5 to 4 millimeters (0.197 to 0.157 inches) the difference in the lengths of test bars was of an order of four divisions. With a considerable burr reducing by about one-half the section of gate the spiral ran out only two divisions, while the same metal run thereafter in a test bar with calibered core reached 11 divisions (Fig. 6). We also show the chart of Fig. 9 which reproduces the data obtained in the experiments. The irregular section of the gate of the core has accordingly a considerable influence on the result. We shall see further on how this cause of imperfection was eliminated.

In tests which followed, with a view to looking into the other factors, we, therefore, made it a point that the tap hole was as exactly dimensioned as possible. Having thus made the experimenting conditions pretty well identical, we found the following points to exist:

(A) *Horizontal position of the mold.*

This factor is very important, a slight incline falsifying entirely the results. In a general way we have noticed that the inclination of the mold was reducing the length of the spiral. This can readily be explained by the tendency which the metal has to drop to the lowest point and stay there. (Fig. 10.)

(B) *Humidity of sand.*

This factor, to our great surprise, does not seemingly interfere at all, even if the humidity is greatly changed. We have run at the same time, molds in very dry sand, whose moisture content did not exceed 3 per cent, and molds made with a sand with 7 per cent moisture, and we have obtained in the two cases substantially the same results. We have gone further by drying a mold with a welding lamp and running it at the same time with another one in moist sand; the difference between the two test bars obtained would reach hardly one division. (Fig. 11.)

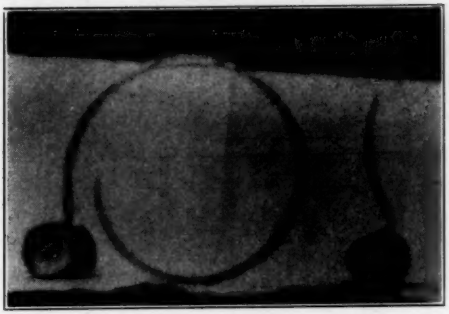

FIG. 6

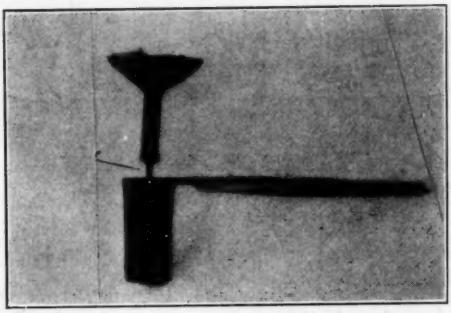

FIG. 7

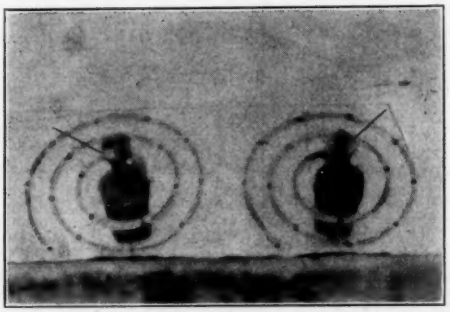

FIG. 8

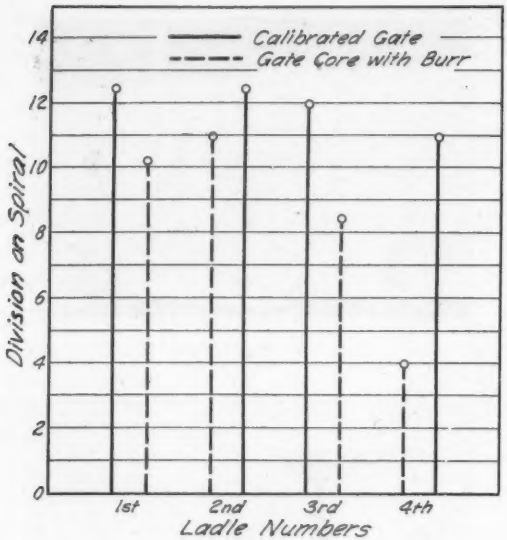
Calibrated Gate
Gate Core with Burr
Division on Spiral
0
2
4
6
8
10
12
14
1st
2nd
3rd
4th
Ladle Numbers

FIG. 9

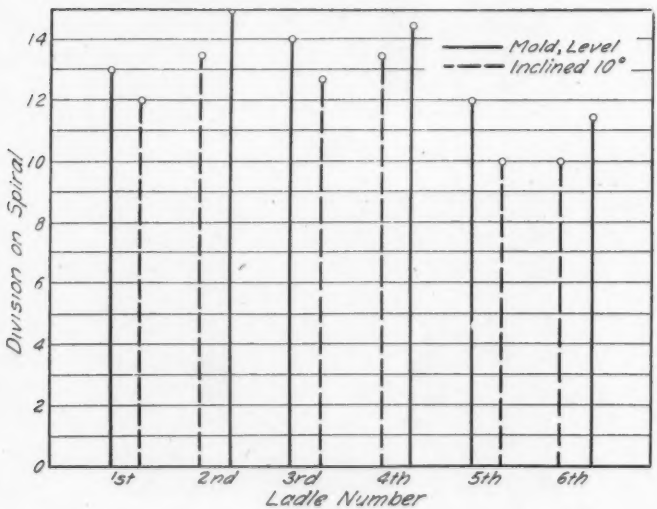
Mold, Level
Inclined 10°
Division on Spiral
0
2
4
6
8
10
12
14
1st
2nd
3rd
4th
5th
6th
Ladle Number

FIG. 10

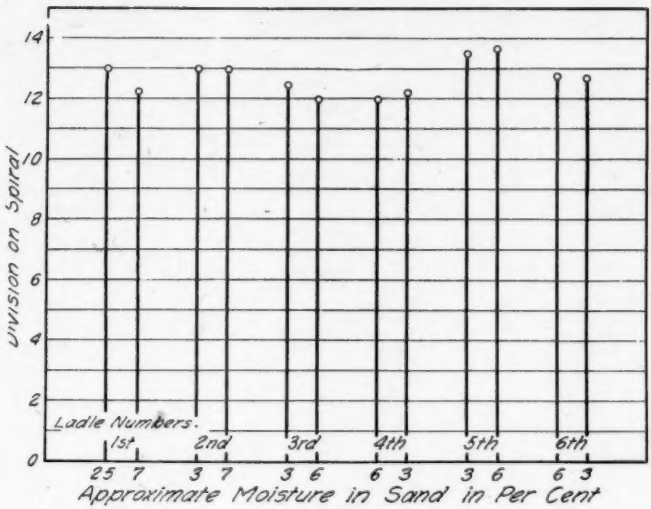

FIG. 11

(C) *Influence of the trapped air at the extremity of the spiral.*

We thought that the gases compressed at the end of the spiral at the moment of the run might oppose a certain resistance to the path of the metal. Experience has shown that this was not the case and that vent holes from 2 millimeters up to 10 millimeters (0.079 to 0.394 inches) and beyond did not influence in any way the results.

These points ascertained, permitted us then to turn our researches on two principal points as follows:

Remedying, if possible, the cause of error arising from the difficulty of exact dimensioning of the core.

Doing away with, or at least decreasing the influence of the inclination of the mold.

The solution of these problems, it has seemed to us, were to be sought in two ways. For the first point by looking into the way of regulating the speed of iron run through the section of the spiral and not through the section of the gate of the core,

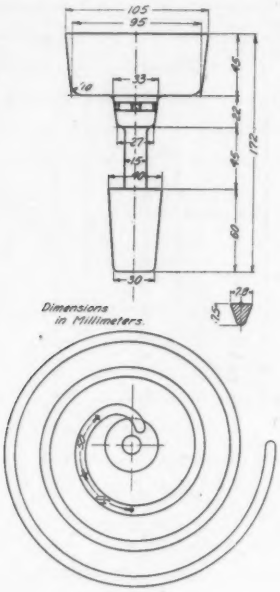

FIG. 12

the latter having only the purpose to avoid the dynamic effect of the stream of metal. For the second point by placing the runner at the center of the mold.

Final Test Bar Design

For this purpose, and at the suggestion of Mr. Ronceray, we changed the test bar in the following manner: The gate is placed in the center of the spiral; the gate is provided with a filter core of a standard form with three filter holes of 8 millimeters (0.315 of an inch) diameter, and the downgate has a section of 15 millimeters (.59 of an inch). The reservoir was reduced in part; it may be reduced still more, as we shall see further on (we give in Fig. 12 a sketch of the test bar thus changed).

When the results of the larger delivery capacity of the gates and filter holes were compared with more sensitive gates when placed in identical conditions, the results remained essentially constant. We have, moreover, been able to note that starting from a certain limit, the increase of section of the holes of the filter of running did not influence the results. This statement is based on experiments made with tests of filter cores with three holes and with two holes, for which we have obtained the same lengths. The photograph (Fig. 8) shows two test bars run at the same time under such conditions.

On the other hand, the role of the reservoir which, in the foregoing test bar, was to obviate the running of iron into the spiral before the complete filling up of the basin, had in the present case only the purpose of receiving the first lot of iron. The experiments made with reservoirs of varying capacity, moreover, clearly indicate that if the path of the metal increases slightly to the proportion in which the capacity of the reservoir increases, the results for one and the same approximate capacity remain constant, and we would say that it is possible to reduce without inconvenience the dimensions of this reservoir. (Fig. 13.)

From the above experiment it can be concluded that the arrangements described permit the obtaining of results that can be compared without varying the factors foreign to the metal, except within limits practically easy to realize. It is sufficient for this purpose to make a mold in green sand under conditions that are very simple, and to run the iron through a core filter of standard design of three holes of 8 millimeters (0.315 of an inch). This affords the advantage of eliminating to a considerable extent, the cause of errors arising from a defect of inexact dimensioning of the filter core holes of 5 millimeters (0.197 of an inch) and in the second place of obtaining with the same metal at the same temperature the largest length of spiral and through this very fact a scale of comparison that can be more easily interpreted. Later on it was found interesting to make a pouring basin avoiding the direct pour on the filter core. The drawing (Fig. 14) shows the changed box and the apparatus as it is made up and employed at present.

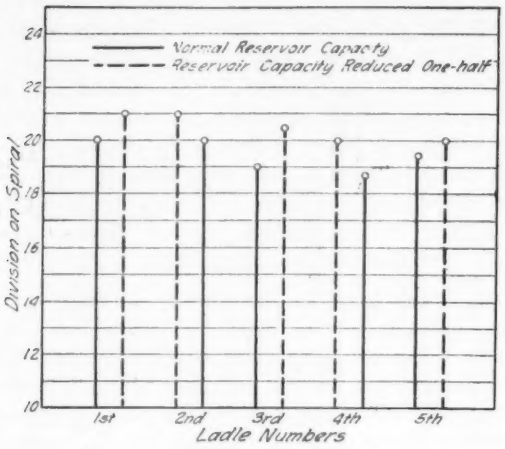

FIG. 13

Effect of Mold Linings

The regular use of this test bar has permitted us to make quite unusually interesting observations. Thus, for instance; the linings of the mold play a very important part on the facility of filling. It has been found that molds lined with graphite give a number of divisions very much higher than a mold with natural sand, and this has permitted us in a foundry to avoid numerous rejections by continuing the use of the graphite, which was about to be discarded.

Settling Arguments

In malleable iron foundries, the molders are often having arguments with the man in charge on the quality and temperature of the metal supplied. In our foundry we are running chiefly very small pieces. The molders are working on a piece work basis. This test bar has become almost indispensable, not only to assure a good run of the pieces, but also to serve as arbitrator between the management and the workmen, this arbitrator per-

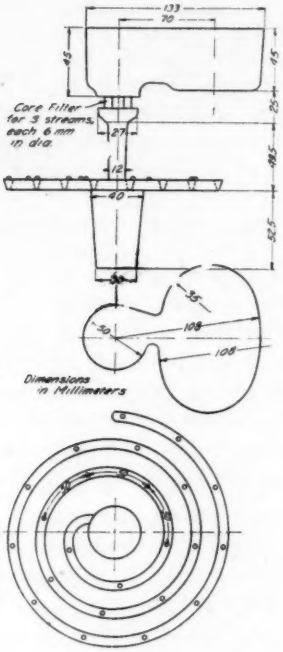

FIG. 14

mitting us to establish without any error the cause of the scrapping. In the manufacture of a special article in great numbers, for instance, we were able to establish a scale of running qualities, in consequence of which we have almost entirely done away with the rejected castings. A ladle of about 40 kilograms (88.2 pounds) giving from 11 to 12 divisions to the test bar, permits us to run a series of molds without misruns. On the other hand, if the same ladle gives about 10 divisions, it is necessary to pig the 8 or 10 kilograms (17.6 or 22 pounds) from the bottom of the ladle in order to obviate the misrunning of the pieces contained in the last molds. Below 8 divisions it was useless to try to run the molds; they will not fill up.

Cupola Control

The test bar is also of great advantage for controlling the operation of the cupolas; running a test bar at any instant permits us to discover immediately any defective feature of the apparatus, whether it be through hanging up of the charges, or through irregularity of charging or oxidizing.

Fluidity Test Applied to Non-Ferrous Work

In the case of foundry work entailing copper alloys, the test bar for running qualities possesses a field of investigation still more extended, because the test bar aside from the measuring of the degree of running ability, gives an indication as to the chemical composition of the alloys poured. Owing to kind aid lent to us by Mr. Thibault, mechanical engineer and manager of operations of a large bronze factory in the Paris district, we have been able to complete our records on this point.

The test bar used was slightly changed in the stopper rod in the basin and by slightly increasing the capacity of the basin, so that its contents are a little above the volume of metal necessary for filling the spiral and its gate.

Thus designed the test bar permitted us, as we said above, to determine the composition of alloys cast, while investigating the running qualities of different typical alloys and by examining the influence of the alloying metals on the different mixtures.

Table 1, listing the data of experiments made by Mr. Thibault, shows the influence of the special elements on the running qualities. These results were obtained with alloys strictly graded, and by running four tests on each alloy.

Another especially interesting point consists in the examination for copper of the best deoxidizer which would be capable at the same time of increasing the very poor running qualities of this metal, while at the same time improving its mechanical qualities.

Having to run very thin pieces in copper, experiments were undertaken by employing successfully as deoxidizing agents,

Table 1

RESULTS OBTAINED WITH THE TEST BAR ON RUNNING QUALITIES OF NON-FERROUS METALS (FOUR EXPERIMENTS PER ALLOY)

	Cu	Sn	Ln	Pb	Ni	Al	Fe	Mn	Th	Si	Miscellaneous	Fluidity Qualities in Division
Copper	99.5	....	....	....	....	....	....	....	....	....	0.5	6*
	93.0	0.85	1.15	0.75	....	....	0.25	....	....	....	....	9†
	92.95	0.65	0.85	....	....	....	....	....	....	1.45	0.05	11‡
	93.0	....	1.50	....	1.42	....	....	....	....	....	0.08	11§
Bronze—B[1]	90.0	8.0	2.0	....	....	....	....	....	....	....	....	14
	90.0	7.5	1.0	1.5	0.05	....	0.25	....	....	....	0.20	18
Bronze—B[2]	86.0	14.0	....	....	....	....	....	....	....	....	....	16
	85.0	13.0	1.22	0.08	0.20	....	0.10	....	....	....	0.40	21
Bronze—B[3]	86.0	12.0	1.88	....	0.04	....	....	....	0.03	....	....	18
Bronze—B[4]	77.0	8.0	....	15.0	....	....	....	....	....	....	....	14
	76.5	7.5	....	14.5	1.0	....	0.5	....	....	....	....	16
Marine—88/12	88.0	12.0	....	....	....	....	....	....	....	....	....	12
	86.16	10.96	1.35	1.42	Traces	....	0.03	....	....	....	0.08	17
Marine—90/10	90.0	10.0	....	....	....	....	....	....	....	....	....	10
	89.94	9.63	....	0.17	0.06	....	0.01	....	....	....	0.19	12
Brass—70/30	70.0	....	30.0	....	....	....	....	....	....	....	....	7
Brass—68/35	65.0	....	35.0	....	....	....	....	....	....	....	....	8
Brass—60/40	60.0	....	40.0	....	....	....	....	....	....	....	....	10
Brass—H. R.	58.2	38.8	....	....	0.5	....	1.0	1.5	....	....	....	12‖
	55.2	37.3	....	....	2.0	2.00	1.5	2.0	....	....	....	18‖
	55.2	36.8	....	....	4.2	....	0.2	2.8	....	....	0.8	14‖

*Metal completely oxidized.

†Metal sound, the spiral is carried back to the straight line, it breaks if the tests of malleability are continued; this is the indication of the presence of Sn and Zn.

‡If the running qualities have been increased, this fact is indicated by breaking of the test bar in hot condition; the pieces are very malleable when in cold condition.

§Has not any increased running qualities nor malleability in increasing the assumed percentage of copper doing away with the effect of Zn.

‖These brasses H. R. run as cold as possible.

zinc, manganese, nickel, phosphorus, aluminum, magnesium and silicon.

All of these have increased the running qualities by three or four divisions, but it is found that the employment of silicon, magnesium and aluminum and even of zinc had the effect of causing the test bars to break on taking them out. This defect was confirmed when running pieces under the same conditions. It would accordingly seem that the best deoxidizing agents to use would be manganese, phosphorus, and nickel, the latter, however, not giving good results except on condition of being incorporated under the form of 50 per cent zinc-nickel.

It was also noticed that with a sound and well oxidized copper, it was possible to straighten the spiral of the test bar and to again roll it in spiral form in a contrary direction. The test bar accordingly has not only given us results on the running qualities and chemical composition of the cast metal, but also on its malleabillity.

Without insisting any further, it can readily be seen how great a use the bronze foundryman can derive from this test bar, which, while informing him on the chemical composition of his metal, will permit him to learn quickly the composition of the scrap used by him and to determine approximately the final composition.

As to brass, owing to the influence exercised by the variation of the ratios between copper and zinc and its effect on the running qualities and malleability, the test bar will also supply to the foundryman several accurate observations.

For instance, it has been found that the running qualities of brass, 65 copper to 35 zinc, will hardly exceed 8 divisions. With the same proportion of copper-zinc if the mark of 8 was exceeded, we found always incorporated in these brasses in small quantities such metals as aluminum, silicon, iron, etc., but at the same time, while the running qualities increased, it was found that the malleability decreased. This is the kind of brass that exhibits high strength. In these alloys the ratio of copper to zinc is always approximately 60 to 40 and, accordingly, it is especially in the examination of metals introduced such as aluminum,

silicon, lead and iron that the test bar will be of considerable aid. In fact, some of these additions will, once in a while, reach 4 to 5 per cent and the great influence is quite well known which they exercise on the assumed composition of the alloy, so that it is very interesting to know them and examine their effect.

In this way a high resistant brass, which possesses high strength with a small percentage of aluminum, has a running property that might reach 18 divisions, while the 60 to 40 ratio gives only 10. Above 14 divisions, the test bar is brittle.

Finally, a last application of the test bar applied to the non-ferrous metals in the case of iron, is in the examination of the influence exercised by the linings of the mold. As an example, it has been found that a brass (65/35) giving 8 divisions to the test bar can be made to give as high as 12 divisions if care is taken to spray on the mold a naphtha residue or linseed oil.

Owing to lack of time, the tests related in this article could not be carried any further; however, we present this paper in its present form, in the hope that the American foundrymen will have the kindness of looking carefully into this plan of testing, making use of it and communicating to us their observations as practice may suggest them. We would be very thankful for any advices which they could give us; these coupled with the experiments that we are continuing, will permit us, so we hope, to improve and perfect still further the test bar which is to tell about the running qualities of the metals cast.

Discussion

J. T. MacKenzie: Gentlemen, this paper, presented on behalf of the Association Technique de Fonderie of France, happens to come in at a very opportune time, when your own Gray Iron Research Committee is intensely concerned with this same question. The results of fluidity tests of the spiral form were published some time ago by Professor Portevin and Guillet before the French Academy of Science, in which they hit on a term that has been sadly needed for some time. This word has been translated "fluidity," but that is not the word that was used in the French. They used the word "coulabilite," which really means "ability to run" and which was defined by Professor Portevin as "Probability of obtaining the molded pieces." You will readily see that that is the summation of all the properties of the liquid metal and includes the specific heat, the thermal

conductivity, the temperature, the evolution of gas content and the viscosity of the metal. You will see they define the word "coulabilite" in the second paragraph of the paper in italics, "The aptitude of a liquid in a given condition to fill a mold prepared under determined conditions."

CHAIRMAN J. W. BOLTON: While this paper and the tests advocated will seem like an old friend to some of us, in that we have seen this spiral strip used for fluidity tests, nevertheless it is at once evident that the authors have given more thorough study to this and brought it even nearer to a real shop test that is of practical value

The title I notice is "Test Bars to Establish the Fluidity Qualities of Cast Iron," and I believe that should have been a little more comprehensive, "to Establish the Fluidity Properties of Various Metals."

J. T. MACKENZIE: It seems to me that the author has neglected to give us any data on temperature, which I am sure would have been of paramount interest. He uses the term "hot iron" and the term "cold iron," but that doesn't mean much, especially on different mixtures. He has stated in the beginning of the paper the great number of conditions which are wrapped up in this fluidity test. Now, we should like to have had some tests on the chemical analysis of the iron in the mixtures and the temperature, because those are the things that could easily have been determined. That would leave, then, the fluidity test itself as a measure of the things we have not yet been able to determine, which are the viscosity and specific heat, etc.

The author says, though, that he has not had time to work this thing out satisfactorily to himself, but he is passing it on for future work. The Research Committee of the Association is very much interested in this work and if anybody does accumulate any data on this strip as shown by Professor Curry, he owes it to the organization to turn it over to the Research Committee, because it will probably save some of us a great deal of work, and we would certainly like to have results on this strip from as many different foundries using as many different irons as possible.

CHAIRMAN J. W. BOLTON: This problem of studying fluidity, of course, is an intricate one and it will take very many years before all the fine points have been argued out.

The Growth of Cast Iron*

By Dr. J. H. Andrew,† D. Sc., Glasgow, Scotland

A glance at the bibliography relating to published researches on the growth of cast iron might give the impression that this problem had been thrashed out in every detail. A perusal of the original papers, however, cannot but impress one with the conflicting results and opinions of the different authors. It is therefore with a view to summing up the conclusions of the different investigators and of putting forward certain reasons for the many discrepancies that this paper is written.

Researches of Okochi and Sato

Probably the first systematic work carried out on the growth problem was that of Okochi and Sato,[1] who, using a dilatometric method of experimenting, came to the following conclusions:

(1) Oxidation does not play an important part in the growth,

(2) Decomposition of cementite is partially responsible for growth,

(3) The gas pressure within the metal is an important feature.

Carpenter and Rugan Findings

Following up the work of Outerbridge,[2] Carpenter and Rugan[3] carried out exhaustive experiments with special irons in

*This paper is one of a series on foundry problems being exchanged between the Institute of British Foundrymen and the American Foundrymen's Association. The first, prepared by the late George K. Elliott, was presented at the 1921 meeting of the Institute of British Foundrymen. The second was presented at the Rochester, New York, meeting of the American Foundrymen's Association by F. J. Cook, past president of the Institute of British Foundrymen. Professor Enrique Touceda presented the third paper before the British Society. The fourth was written by Dr. Percy Longmuir; the fifth by Major R. A. Bull; the sixth by Wesley Lambert and G. Hall; the seventh by Dr. R. J. Anderson and M. E. Boyd; the eighth by J. E. Fletcher; the ninth by Dr. H. Ries; the tenth by Arnold J. Lenz; the eleventh by John Shaw. This, the twelfth of the series, is to be followed by the thirteenth paper by J. T. MacKenzie, which will be presented at the July, 1927, meeting of the Institute of British Foundrymen. Professor John H. Andrew, the author of this paper, is Doctor of Science and Professor of Metallurgy of the Royal Technical College, Glasgow, Scotland. Dr. Andrew's work on the growth of gray iron is especially notable.

†Professor of Metallurgy, Royal Technical College.

[1] Okochi and Sato, Journal College of Engineering, Univ. of Tokio, 1920, vol. X, No. 3.

[2] Outerbridge, Journal Franklin Inst., 1904, vol. 157.

[3] Carpenter and Rugan, Journal Iron and Steel Inst., 1909, No. 2, and 1911, No. 2.

which silicon and other elements were allowed to vary, one at a time. Their conclusions were:

(1) Growth is largely due to the oxidation of the silico-ferrite,

(2) Graphitization of the cementite is partially responsible for growth,

(3) Phosphorus and especially manganese diminish growth,

(4) A white iron will not grow so long as it remains white.

Dilatometric Test Results of Kikuta

In 1922 Kikuta[4] published his results obtained by using a dilatometric method similar to that of Okochi and Sato. From leakage tests carried out to determine the evolution of gas from the specimen at different temperatures and after different heatings, he found that the leakage rate increased slightly with the temperature for the first twenty-one heats, and increased with the numbers of heatings up to about sixty heats. From these experiments he concluded that gas pressure cannot be regarded as being responsible for much of the growth. From the results of his dilatation experiments he concluded that:

(1) Graphitization of cementite brings about a certain amount of growth during the first heating,

(2) Indirect oxidation in which the oxide when formed fills the fissures and cavities during the A_1 transformation is partially responsible for growth,

(3) The greater part of the expansion is due to the minute cavities or fissures formed by the irreversible expansion in different microportions of the specimen.

Curiously enough he states that the elongation observable at temperatures above A_1 is due to the presence of occluded gases, as conceived by Okochi and Sato. The oxidation theory of Carpenter and Rugan is, he says, untenable.

Conclusions Reached by Andrew and Hyman

Andrew and Hyman[5] using a method similar to that of Carpenter came to the following conclusions:

[4] Kikuta, Sci. Reports, vol. 11, No. 1, 1922.

[5] Andrew and Hyman, Journal Iron and Steel Inst., 1924, No. 1.

(1) The growth of cast iron takes place in two stages. The first is the rapid stage, and is due to oxidation of the ferrite. The second stage, i. e., the slower stage, is marked by a rapid oxidation of the free graphite, which is replaced by oxide material.

(2) From their experiments on nickel iron in which the permanent growth was as pronounced as it was in the silicon irons they suggested that the influence of such graphitising elements as silicon aluminium and nickel was by virtue of their effect upon the form of graphite, which on account of their presence existed in the form of very large and thick flakes. The penetration of gas through a large and thick flake would take place more easily than it would through a thin one.

The most recent work is that of Pearson.[6] This author, after carrying out experiments similar to those of Carpenter, supports the latter author in most of his conclusions. He further confirms the work of Andrew and Hyman in that the form of the graphite flake influences the rate of growth. Andrew and Higgins[7] using a form of dilatometer different from that of the Japanese workers carried out a series of tests on irons which varied in manganese and phosphorus. Since the conditions under which these experiments were performed are peculiar to themselves this work will be dealt with later.

Research Workers Draw Varying Conclusions

This brief summary of work done is sufficient to show that while certain conformity of viewpoint does exist, the different workers are by no means unanimous in their opinions.

Most of the investigators in this field agree that graphitisation is responsible for a certain part of the growth. Moreover, the results of the many observers who have conducted growth experiments in vacuo all seem to point to the necessity of air or an oxidising gas as being an instrumental factor. This is further substantiated by Pearson, who found that only a slight permanent expansion occurred after conducting the heating in an atmosphere of hydrogen.

Although the Japanese workers would seem to regard oxida-

[6] Pearson, Carnegie Memoirs of Iron and Steel Inst., 1926.
[7] Andrew and Higgins, Journal Iron and Steel Inst., 1925, No. 2.

tion of the ferrite as a secondary factor, the experiments of Carpenter, Pearson, Andrew and Hyman strongly point to this reaction as being a primary factor. Further, Pearson, by using a carbon dioxide atmosphere in place of air, obtained much greater growth. In favor of the oxide theory may be cited the following proof:

(1) The irons of Carpenter high in silicon eventually disintegrated; this is strong evidence of the formation of some bulky material such as iron or silicon oxide forming within the specimens. This worker along with Pearson, and Andrew and Hyman further found an increase in weight corresponding to the increase in volume. It is obvious that the only material that could be added in these experiments is oxygen. Pearson on separating the silicon from the silica in his treated specimens found that silicon became changed into silica as the number of heatings increased.

Andrew and Hyman found that after fifty heats certain of their irons showed a complete absence of carbon, each graphite flake being oxidised and its place taken by oxide of iron, which when separated and analysed was found to have the composition Fe_3O_4.

The presence of oxide as a micro constituent was further confirmed by Andrew and Higgins.

Oxidation of Iron Preceded by Oxidation of Graphite

That oxidation of the iron preceded oxidation of graphite was pointed out by Andrew and Hyman, who found that in the first rapid period of growth the carbon content fell very little, when, however, the second and less rapid growth stage was reached the graphite became rapidly oxidised as the heatings continued. Further during the initial stages of graphitic oxidation a decrease in weight of the specimens took place, which is further confirmation of this view.

The methods employed by different workers may be classified into two categories, namely, the method of heating and cooling the irons in a furnace and measuring the increase in length and diameter after each successive treatment, and secondly, that of successively heating and cooling the specimens in a dilatometer and

measuring their increase in length through the temperature range. As an example of the first method Fig. 1 is a comparison between the determinations of Carpenter, Pearson, and Andrew and Hyman, the irons selected for this purpose being as follows:

	Total Carbon	Silicon	Manganese
Carpenter (a)	3.98	1.79	0.23
Pearson (b)	3.77	1.55	0.87
Andrew and Hyman (c)	3.33	1.31	0.58

An interesting feature with respect to the three curves is the extraordinary similarity between the curve of Carpenter and that of Andrew and Hyman. Both of these curves show the beginning

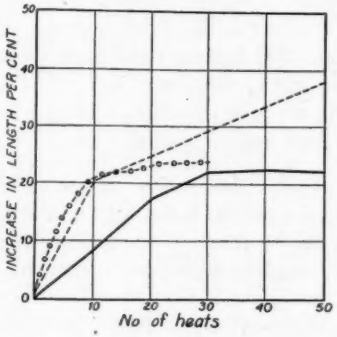

FIG. 1

of the second period of growth between the tenth and fifteenth heat, the amount of growth up to this stage being similar in both examples. The only difference with respect to the two curves is that the curve of Andrew and Hyman shows the growth to take place continuously whereas in the example from Carpenter growth practically ceases after thirty heats. This difference can be easily accounted for by the fact that the specimen of Andrew and Hyman became badly oxidised on the surface after thirty heats, thus increasing the superficial volume.

The difference in character between the two curves just considered and that of Pearson is marked. In the example taken from Pearson the primary growth period continues to thirty heats.

The peculiar fuzziness of the graphite flakes during the period of growth, particularly in the earlier stages, has been commented upon by many, and has usually been considered to have been due to admixture of oxide particles with the graphite. This feature along with the fact that oxidation of the iron precedes that of the carbon merits consideration, and it might be interesting to examine some possible reactions to account for the phenomena.

According to Eastman,[8] at temperatures between 0 degrees Cent. and about 600 degrees Cent. the reaction $2CO = C + CO_2$ will proceed from left to right. At temperatures above 600 degrees Cent. according to the ratio $\frac{CO_2}{CO}$ the reaction may proceed from right to left.

Further, below 600 degrees Cent. with a certain CO_2 — CO ratio the reaction $3Fe + 4CO = Fe_3O_4 + C$ will also proceed from left to right, this reaction likewise being reversible, depending upon temperature and CO_2 to CO ratio.

It is quite possible that at low temperatures oxygen of the air combines with the carbon to form CO_2, and that this is immediately reacted upon by the iron on raising the temperature with the formation of magnetic oxide and carbon monoxide according to the equation

$$3Fe + 4CO_2 = Fe_3O_4 + 4CO.$$

On lowering the temperature again, the reaction $3Fe + 4CO = Fe_3O_4 + C$ might take place, giving rise to the fuzzy carbon already referred to. According to this suggestion a certain amount of the graphite consumed by the air would be redeposited as free carbon on cooling, while Fe_3O_4 would at the same time continue to form. Further, the reaction $2CO = C + CO_2$ might easily take place at the lower temperatures in presence of the catalyst iron and iron oxide.

That the formation of Fe_3O_4 along with a certain deposition of carbon does take place, and that this reaction is moderately rapid is evidenced by the curves of Andrew and Higgins, which show an extraordinary and sudden expansion of the system begin-

[8] Eastman, Journal Amer. Chem. Soc., 1922.

ning at a temperature of 600 degrees Cent. after a certain number of heats. A hypothetical figure has been drawn (Fig. 2) which indicates the general form of the curves for a cast iron containing about 4.0 to 4.5 per cent of carbon and 1.5 per cent of silicon. The curves drawn in this figure represent generally the type of curve obtained in the series of irons with varying manganese, the only difference between the different manganese contents being not in form but with respect to the position of the curve in the order of number of heats. For instance, with the high manganese series the form III persisted for several heats, but was eventually followed by curves of the type of IV and that of type V. A

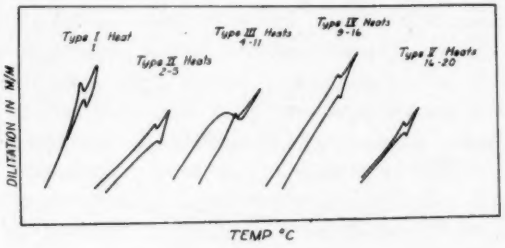

FIG. 2

peculiar feature noted was that the heat preceding that which gave the large expansion on cooling invariably showed an excessively large coefficient of expansion during heating. Indeed, the variation in the coefficient of expansion during the different heatings was a noticeable feature of this work. This in itself supports the contention of Kikuta who would appear to assume that the growth is largely brought about by abnormal expansions and contractions undergone by the different micro constituents. The author would, however, further suggest that the large expansion following upon a marked and sudden expansion on the previous cooling may be due to the newly formed material such as Fe_3O_4, and possibly, in the earlier stages, deposited carbon, not being able to occupy their normal volume at the time of their formation. Upon heating up they are enabled to expand and so occupy their normal spacings.

The contraction sometimes met with at later heats would seem

to be due to the Fe_3O_4 segregating and occupying blow holes and the spaces left by the graphite. The results of Pearson, which show an increased growth in an atmosphere of CO_2 as compared with air, give further support to this contention. Up to the present it has been assumed that normal types of cast iron were being dealt with. Of the special irons Carpenter has shown that high manganese in the absence of high silicon considerably reduces the rate of growth. Andrew and Higgins found that, provided the silicon content was about 1.5 per cent, little difference was observed with a manganese content varying between 2.0 and 5.5 per cent. Indeed, manganese seemed to accelerate rather than reduce growth. A peculiar feature in the manganese irons was the sudden breakdown in patches of the manganese-iron-carbide. Micro examination showed that in the same specimen there often occurred patches of manganese-iron-carbide perfectly intact, while other patches had completely broken down into free carbon. When once the decomposition of the manganese carbide had been brought about, it was only to be expected that, manganese being a highly oxidisible element, growth would be accentuated, and this was a fact. The free manganese being in the nature of a decomposition product would be in an extremely fine state of division and most readily oxidised by the air. Phosphorus presents a more difficult problem, and in summing up their work Andrew and Higgins were unable to make any definite statement with respect to the action of phosphorus.

Certain facts are however borne out by their experiments, namely, that a phosphide-iron-carbon eutectic is more stable than the pure iron carbide eutectoid, it would seem as if the phosphorus prevented the carbide of iron from decomposing. That this is so is evidenced by the fact that with the lowest phosphorus iron selected for their experiments, which had a phosphorus content of 1.30, practically the whole of the combined carbon was graphitised during the first cooling. As the phosphorus content increased, however, the process of graphitisation became slower. Another peculiar feature with respect to the higher phosphorus irons containing phosphorus from 2 to 4 per cent was the marked contraction which took place on soaking at 900 degrees Cent. This was

found to be due to the phosphide of iron liquating, and filling in the free spaces left by the graphite and those due to blowholes.

Phosphorus, although uncertain in its effects, would seem to slightly increase the growth of iron.

Viewing the effect of the different elements upon the growth of iron, it would seem that elements which accelerated the graphitization of the carbide such as silicon aluminum and nickel increased growth, while elements such as manganese in the absence of elements of the first class, chromium, and other carbide forming element, also carbide stabilizers such as sulphur, would tend to decrease the growth. In other words, it would seem that it is only those elements which will give an unmachinable white iron which will retard to any extent the rate or magnitude of growth.

Growth on Heating to Below 700 Degrees Cent.

With respect to what may be described as low temperature growth, the recent work of Higgins[9] brings to light many interesting facts. His low temperature dilatation curves give one the impression that low temperature growth is due to the same phenomena as is high temperature growth. His curves show a marked variation in the coefficient of expansion, which corresponds with the same feature in the high temperature curves of Andrew and Higgins. His photomicrographs show conclusively that formation of oxide of iron takes place readily, and that it is this reaction which is chiefly instrumental in bringing about the expansion. That the greater part of the carbon remains unattacked is evident also from his photos, although a certain fuzziness along the graphite flakes points to the formation of Fe_3O_4 along with a deposition of carbon.

It must not be overlooked that the deposited carbon is the result of a high temperature reaction in which the graphite becomes oxidized, followed by a further reaction in which the CO or CO_2 again breaks down with deposition of carbon. The term high temperature reaction is of course used relatively.

[9] Higgins, Carnegie Memoirs of Iron and Steel Inst., 1926.

Low and High Temperature Growth in General

When the extraordinary heterogeneity of cast iron is taken into account, it becomes more remarkable to find such an extraordinary agreement between the results of Carpenter and Andrew and Hyman. In considering the factors involved in the growth, the particular configuration of the micro constituents must not be lost sight of. If, as in most cases, the type of section experimented with is in the form of a round bar, then the angle which the graphite flakes makes to the longitudinal direction here of the bar must not be overlooked. Supposing, for instance, that in one case the graphite flakes which have become filled with oxide material lie in a direction parallel to the length of the bar under test, and in another case that they all lie at right angles to the length. It is obvious that the expansion along the length and across the diameter will be different in the two cases, and whereas the total increase in volume would be the same in both cases, the measurement in the increment in diameter of the bar cannot be as accurate as one taken along the length. This is in no way due to inaccuracies in actual measurement but rather to the fact that surface oxidation will have a greater effect upon the diameter than upon the length. The particular arrangement and size of the micro constituents will therefore have an appreciable effect not only upon the magnitude but upon the rate of growth, and also upon the coefficient of expansion over the whole range of temperature employed.

It would seem quite evident that, as has previously been stated, no machinable iron can resist the powers that bring about its growth. The rate of growth may be retarded by the addition of certain elements, but provided any iron is continuously heated and cooled for a very large number of heats, growth will invariably take place. Even in the chromium irons experimented upon by Andrew and Hyman, the temper carbon which formed by decomposition of the chromium carbide gradually became replaced by oxide material, showing that growth was purely a question of degree and of time.

It would seem that the only way of preventing growth would be to deposit on the surface of the iron some metal or other substance which is impermeable to gases, thus preventing access

of air to the graphite flakes and therefore to the interior of the casting. Even then graphitization of the combined carbon would still bring about a certain amount of permanent expansion.

Conclusions

From the work of others and his own the author has come to the following conclusions respecting the underlying causes of growth in cast irons. Growth is brought about as follows:

(1) By graphitization of combined carbon;

(2) By percolation of air through the graphite flakes and channels in the iron bringing about oxidation of the ferrite, with the formation of Fe_3O_4, and probably finely deposited carbon.

(3) A certain amount of contraction will eventually result from oxidation of the graphite and deposited carbon, but this may be balanced by further and continuous oxidation of the ferrite;

(4) Every time the iron is heated and cooled its structure will be changed due to the previous treatment, with the result that the coefficient of expansion will have altered. Further, the expansion of oxide material and direction in which this lies with respect to the length of the section employed will bring about a difference in total expansion at every heat, and will result in a breaking apart of the particles at certain areas, which in itself will cause growth;

(5) The author does not think that occluded gases, or rather their physical effect, can bring about any permanent expansion. Oxidized gases in reacting with the iron or the carbon will of course have the same effect as similar gases added externally.

Discussion

J. T. MacKenzie: Dr. Andrew's paper gives a very fine summary of the work that has been done up to date. This is in connection with the question of growth caused by oxidation. There is, however, a growth of cast iron that is independent of oxidation, as Dr. Benedict of the Swedish National Physical Laboratory, I believe, has shown in a recent paper read

before the British Iron and Steel Institute. Theoretically, a cylinder of pure homogeneous metal will distort on repeated heatings and coolings. When you heat it outside, it lengthens and tends to increase the diameter and the outside then cooling, will pull down the length of the cylinder so that a cylinder will, on repeated heating and cooling, take on an onion shape. Now, that is very slow but it has an influence, especially in the case of rapid heating and cooling.

Then, the localized cooling, especially on the surface of cast iron, will produce cracks where there are no graphite flakes to work on, and no metal after it has developed a crack will have the same specific gravity or occupy exactly the same volume; and these cracks can form by a simple rapid cooling independently of any oxidation. Of course, when you have the castings in hot air, the problem of oxidation so much overweighs these other considerations that, as Dr. Andrew has said, it resolves itself to all practical purposes into a question of oxidation.

E. J. LOWRY: It seems to me that the statement on page 309 that growth comes by two stages, the first stage being rapid, due to the oxidation of ferrite, and the second stage a slower one, due to the rapid oxidation of free graphite, should be qualified, because your rate of growth or rate of expansion is relative, relative to the silicon analysis, which is present in the iron. I believe that if the author had, in drawing his conclusions, also included the No. 1 shown on page 3 of the findings of Outerbridge which attributes the growth due to the oxidation of the silico-ferrite, he would have made the paper much stronger. I know that in the experiments that I have been running on expansion, the lower the silicon, the less the growth. For instance, if you take a 1 per cent silicon iron and a 2 per cent silicon iron, you will find that the 1 per cent silicon iron will be about 30 per cent less in growth than the 2 per cent iron.

R. B. SCHAAL: I want to ask Mr. Lowry whether in his experiments on growth—involving the amount of silicon present—whether he has done any experimenting on an iron where the silicon was constant but the total carbon varied.

E. J. LOWRY: Yes, I have performed experiments in both cases. You will find that your greatest difference is when there is a difference in the silicon rather than a difference in the total carbon. For instance, you can take the total carbon of an iron at 3 per cent and one at 3.50 per cent, and approximately there will not be 5 per cent difference in the amount of expansion.

Every one of your curves on growth must be measured by a dilatation instrument of some sort. For instance, the author shows you curves he had taken on a dilatometric instrument and measures growth by that way. Every paper that has been published has been published along the lines of dilatometric observations.

An Expression of Views on the Use of Iron Scrap in the Blast Furnace

By David McLain,* Milwaukee, Wis.

The writer appreciates the efforts of the A. F. A. and the members of its Committee on Cast Iron to secure expressions of opinion on the use of scrap iron in blast furnace practice and its effects upon the product as used by our foundries.

Having bought pig iron on exacting chemical specifications for the past 25 years or more, we have had but an occasional complaint to make after receiving our chemist's report on the shipments. Therefore, on a personal basis, I have no objection to the blast furnace operator using scrap iron, although we do not advise it, as there is a vast tonnage of gray iron scrap on the market that is looked upon with suspicion by foundrymen, but perhaps this scrap might be purified if it were run through the blast furnace with the proper kind of ore.

Gray iron scrap has been used in making pig iron for many years by some operators both here and abroad, but the writer prefers the addition of plain carbon steel scrap, as it is the purest metal charged in either cupolas or blast furnaces and being low in phosphorus, it produces the strongest pig iron.

Ores containing medium phosphorus which produce pig iron with 0.5 to 0.6 per cent phosphorus if reduced with steel scrap will produce a still lower phosphorus pig, the reduction of phosphorus depending on the percentage of steel scrap used.

It is common in gray iron foundry practice to use as much steel as possible when strong castings are wanted and there is only high phosphorus pig in the yard. If 50 per cent steel with 0.06 phosphorus and 50 per cent pig containing 1.0 phosphorus is used, the resultant metal will contain approximately 0.5 phosphorus, which is an ideal amount for many classes of light castings.

*McLain's System, Inc.

To the writer's knowledge steel scrap is being used, and has been used in blast furnace practice since 1911 or 1912, to produce low phosphorus pig iron for ingot molds.

The writer does not believe that the mere fact that scrap is charged into the blast furnace is responsible for the dissatisfaction with foundry irons that seems to underlie this discussion. That good scrap in itself is deleterious when added to the pig iron is open to question. The foundryman, after all, is concerned with the qualities and chemical contents of the pig iron that emerges from the blast furnace and is sold to him for the manufacture of castings.

That chemical analyses may not tell the whole story, is the opinion advanced by many who hold that scrap in the blast furnace is injurious. That also is the writer's opinion, if by chemical analyses we refer to the present practice of absolute dependence upon the percentage of carbon, silicon, sulphur and manganese in the pig iron. The microscopic study of a metal often is the next step when a pig iron of apparently correct analysis fails in a casting, and the conditions found are ascribed in some cases to be the faults of the ore or scrap charged into the blast furnace from which the metal was tapped.

Instead of a microscopic study of metal that failed ***shouldn't the chemist dig deeper*** into the ***mysteries*** of ***pig iron*** from which the castings are made?

Chemists more than 100 years ago claimed pig iron was a very complicated metal. In 1830 Karsten in his "Metallurgy" (French edition) in addition to carbon, silicon, sulphur, phosphorus and manganese also found calcium, magnesium and chromium in pig iron, and it is mentioned that the purest pig irons are quite complex compounds.

The U. S. Bureau of Standards' analyses give the following metals and metalloids in cast iron:

1. Total carbon (direct combustion).
2. Graphite (combustion).
3. Combined carbon.
4. Silicon.
5. Sulphur.

6. Phosphorus.
7. Manganese.
8. Titanium.
9. Copper.
10. Vanadium.
11. Chromium.
12. Nickel.
13. Oxygen.
14. Nitrogen.
15. Hydrogen.
16. Arsenic.

While the presence of these elements has been established, their exact effect, in many cases, is not known. Besides this, there exist too few studies on the influences of variations in melting temperatures and cooling rate upon the properties of the pig iron. However, the influences of composition and melting conditions are reflected in the structure of the iron.

We buy iron upon analysis. Few picture to themselves just how these elements may occur in the structure of the metal. The elements are not present as such in the iron. Silicon, for example, is thought to exist as silicide in solid solution in the ferritic portions of gray iron. (Both in the massive and pearlitic ferrites.) Its action is largely indirect, and on the carbons. Up to certain percentages it breaks down the original combined carbon (cementite) and it also lowers the eutectic percentage of carbon. Graphite carbon occurs as such, in pencil-like flakes throughout the metal. It is much lighter than the iron. Therefore 3.00 per cent of graphite carbon shown on analysis, which give the per cent in weight, is actually about 12 per cent by volume. It is no wonder, then, that so large a volume of weak graphite should have so great an effect on the strength and shock resistance of cast iron. The combined carbon (in true gray irons) goes to form pearlite, a strong structure. One part of combined carbon gives about 120 parts of pearlite. Phosphorus often occurs in an eutectic formation containing about 10 per cent phosphorus and 90 per cent iron. Thus 0.5 per cent phosphorus would give about 5 per cent by volume of the hard brittle eutectic. When one considers that this phosphorus eutectic often occurs in a network formation, the

reasons for the brittleness of certain high phosphorus irons becomes more readily apparent.

While we know fairly closely the relationship between the final structure of irons and their physical properties, almost nothing is known of the relation of the original or pig iron structure to the metal coming out of the cupola. It has been proved, both in theory and practice, that there are certain inherent properties of the pig iron that are not completely obliterated in cupola melting. Furthermore, the relationship of blast furnace practice to the structure of the pig iron is veiled in deepest mystery. More facts are needed.

In conclusion I would like to summarize the viewpoint stated. Scrap metal is being charged into blast furnaces from time to time. The fact that scrap is used is not in itself an evidence that the metal tapped from the furnace will be of poor quality for castings. The advantages of steel scrap in the cupola have revolutionized the manufacture of high quality irons. The weakest cupola metals are produced by very high percentages of pig iron, not by scrap. Foundrymen should know their requirements in the chemical constituents of the pig iron, and should encourage all research which seeks to probe even further into the effects of manufacture of pig iron upon its structure. Insistence upon the correct analysis specification being met will clear up most apparent difficulties, and closer study of pig iron structure will ultimately explain other differences which may exist.

The Evaluation of Foundry Pig Iron

By Dr. Richard Moldenke, Watchung, N. J.

The desirability of fixing upon some standard method of evaluating the quality of foundry pig irons was first brought to the attention of the industry by the writer in a memorial presented before the American Foundrymen's Association in convention at Boston in 1902. In the year following, he elaborated the subject in a paper read before the New England Foundrymen's Association, in which he again urged the foundrymen to take some action in view of the growing difficulties experienced with pig irons of otherwise good composition. If an investigation of this subject was desirable then, it is certainly necessary now, in view of the post-war exigencies compelling furnacemen to cheapen production costs in every direction to remain active. The constant cry for more tonnage from the furnaces has led to the practice of surcharging the burden with high percentages of scrap bought as cheaply as possible, so that many furnaces today have become huge cupolas for remelting and desulphurizing cast iron scrap, while still reducing almost as much ore as heretofore in the regular way. When it is stated that scrap additions have enabled the blast furnace to effect a saving in coke of 30 per cent and a tonnage increase of 60 per cent, the foundryman has every reason to become worried.

While nothing came of the appeal made by the writer twenty-five years ago, nevertheless occasionally the technical press would record cases where foundrymen had difficulties in getting castings free from blow-holes and gas phenomena, only to get out of trouble when one or more of the brands of pig iron used were changed. The years 1921 and 1922 find articles written by J. E. Fletcher and Y. A. Dyer giving some interesting facts in this connection, and as things got worse the foundrymen of Germany appointed a committee to dig out data and work out a remedy. The raising of scrap prices sufficiently to make its use unprofitable relieved

this committee of its work at the time. The American Foundrymen's Association has the question up also and is planning work co-operatively with the furnace interests, and it is to be hoped that something tangible may be worked out in the not too distant future.

In the meantime, however, there is no immediate prospect of a solution before the foundry industry, and the use of scrap in large quantities in the blast furnace will persist no matter what is urged against it, so long as there is a dollar to be made and a market still to be had. Individual large foundry interests are consequently beginning to take cognizance of the situation and are planning to contract with satisfactory sources for "all ore" pig irons at special prices covering profit losses through tonnage reduction during the life of the order. After all, however, this will amount to giving a better price for a higher grade pig iron, just as charcoal pig iron commands a premium over the ordinary coke irons. And as necessity causes this discrimination against the ordinary run of pig iron of today for foundry purposes to spread, it will be part of wisdom for both foundry and furnace interests to co-ordinate these tendencies and bring them into line with the smallest possible market disturbance. This will mean a standard method of evaluating foundry pig irons, as based upon quality.

Just what such a standard method will be when fully developed is hard to say. The foundryman of today tests out a car-load of some new iron by getting as much of it into his mixture as possible, repeating until he is satisfied that the sprues he recharges have acquired the characteristics of the new iron, and then makes comparative physical tests with the new as against his old brand records. Upon the results thus obtained the new iron is either rejected or added to the list of eligible brands for the class of castings to be made. Yet, this is a crude, even if practical way of dealing with the situation, and may work hardship to the furnace or cut out an opportunity for the foundry for good service if it happens that the test results are close to the line and the tests are not carried out by fully competent men. Too many elements of uncertainty enter into the operating details and some little thing may turn the results one way or the other. Just a case in point. With a close supervision of the coke and

iron ratio for cupola charging, a marked variation in the size of the pieces of coke from one day to the next will make a difference in the temperature of the iron tapped out. With dull iron, especially if carried a long distance and poured into a number of molds from one ladle, the loss of castings is bound to be higher than if a greater liberality with the coke had given fine hot iron with a good life. The poor results thus obtained might condemn a new pig iron, whereas the melting practice was to blame. A standard method of testing pig iron for its quality would have to be a laboratory operation and under circumstances which permit reducing the number of variables entering into the problem to the smallest number possible and have these under reasonably accurate check control.

The change from fracture grading to chemical control in the merchandising of pig iron, while bitterly fought at the time, proved a blessing to the furnaces in the end, for it led to greater uniformity in product, a surer production of the compositions desired, the cutting off of the great bulk of complaints by foundrymen, the segregation of those foundrymen who might be termed hopeless for using irons by analysis, and the opening of the world as a market for pig irons of all countries so long as the analyses were guaranteed. That this blessing has, however, proven to be not an entirely unmixed one, must be laid to the fact that our present analytical methods do not give the full analysis of the iron. Were it possible at this day to add a few items to the list of the usual determinations, so that dissolved iron oxide, nitrogen, possibly hydrogen, the actual combinations existing on the part of the contained sulphur and phosphorus, an entirely different picture of the value of a pig iron might be had. This question, though understood and worked upon, is not likely to be settled in the near future, and hence something of more immediate value in the way of a solution is required.

Perhaps no developments of interest to the gray iron foundry brought out in recent times have such potent possibilities as the extreme superheating of cast iron and the synthetic production of that material from steel scrap. This was presented to the American Foundrymen's Association at the Detroit Convention of last year in the paper by Prof. Piwowarsky. Apart from his

highly interesting theory of graphite nuclei in molten iron of ordinary superheat being responsible for a lower physical strength, and the removal of these nuclei through intense superheating giving a much better and stronger material, the one point he did not bring out specifically is that under the extremely high temperatures prevailing in a bath of the molten metal as he wants it, there is every chance for a thorough deoxidation by the reaction between the carbon present with any iron oxide that might be in solution. Consequently, if this reasoning of the writer be true, there is a chance to correct the irons made under bad blast furnace practice, the difficulties resulting from excessive scrap percentages in the foundry mixture, and any poor melting practice previous to the additional intensive superheating; and then to obtain a high grade molten iron for pouring off the molds in spite of poor quality pig irons. However, such a procedure involves additional expense in melting and makes the metal in the ladle more costly. Moreover, it is better practice to start with good material in the first place than later to correct that which is admittedly poor. Again, this does not solve the question of differentiating between the "all-ore" operating furnace and the one which remelts large percentages of scrap. Surely the careful and conscientious furnaceman is entitled to the best market price and the maker of low quality metal should be penalized.

So, while the indications are that the foundryman can overcome the handicap of poor foundry pig irons by this new method of intense superheating, and further, so long as the price of scrap permits it, furnaces will—more or less—continue the practice of using it; the foundryman will find himself between the alternatives of paying extra money for getting good castings by way of intensely superheating, and also paying extra when making certain of getting high grade foundry pig irons. Between these two alternatives he will choose the well-made pig iron every time, for he can then still add the high superheat if the quality of work demanded requires it.

No matter how the question is turned and considered it comes back to working out a standard method of testing pig iron for its quality. This may be by melting pieces of the pig iron to be tested in an electric resistance furnace, under pyrometer control,

so that no higher superheat is attained than that required for a standard pouring temperature. Then making test bars and testing them for comparison with similar tests with the bars from other known brands of pig iron for that particular foundry. This naturally involves the effect of the chemical composition upon the physical properties brought out by the tests. In such a method, with the standardization of the degree of superheat attained, a standard pouring temperature; with standard test bars and molds in which they are made, standard physical tests and analytical results, there remain practically only the gathering of data and their study to interpret such test results into quality measures of foundry pig iron. This is no small work and would engage the attention of foundry and furnace metallurgists and engineers a long time. Possibly some other, better way can be suggested to replace the present cut-and-try method by way of the cupola, but that something must be done about the situation, and that without great delay, is patent to every close observer of the trend of blast furnace practice so far as the production of foundry pig irons is concerned.

Conference on the Qualities of Pig Iron for Casting Purposes

CHAIRMAN R. H. SWEETSER: There is something occurring in pig iron production which we do not understand. The blast furnace men will admit that instead of using a pound and one-quarter or a pound and one-half of coke per pound of pig iron, some of them are using only three-quarters of a pound of coke. It has been said by some foundrymen that that has made a poorer quality of pig iron. Some blast furnace men are using scrap in their mixture to enrich the mixture. Some foundrymen have said that that has made a poorer quality of pig iron.

Now this round table discussion with the foundrymen and with the technical men and with the blast furnace men present is for the purpose of getting at the facts, and we want to have in our discussions this afternoon a concerted action towards getting the facts in regard to blast furnace practice in relation to the qualities of pig iron. There was a similar meeting in New York last February where the open hearth men and the malleable iron men and the blast furnace men and the scientists came together and discussed this problem. It is a big problem and no one group of men can solve it.

The Department of Commerce has sent three representatives here to attend this conference, two representatives of the Bureau of Mines and one representative of the Bureau of Standards. The question has become a big question and we are in hopes that we can solve some of the troubles.

The first paper on the list today is "The Evaluation of Foundry Pig Iron," by Dr. Richard Moldenke. (This paper will be found on page 323).

C. C. KAWIN: I am interested in knowing why foundrymen can tell that the scrap in the pig iron should make it worse or better. We make car wheels today, with desulphurizers, such as purite, using as high at 92 per cent of scrap in them, but the car wheel is not any worse for that amount of scrap. I worked in those plants for seven years and that was my experience. If scrap is detrimental I would like to get the actual facts. If we could get some figures, I would like to put them out and have our men experiment with them and bring in these facts. I have had a lot of conflicts with the pig iron men in the last 25 years, plenty of them, but I have no grievance with them at all and we are all interested in one subject. The worst materials in many cases will make the strongest iron. Steel scrap with a mixture of low phosphorus and high sulphur makes a stronger iron; steel scrap reduces your phosphorus and makes a stronger iron, and your sulphur, within certain limitations, will increase the strength of your iron. Consequently, if there is something wrong with that practice, I would like to get that information in some form that we could experiment

with it and bring in the facts to the Foundrymen's Association. Are there any definite data on this question, data on work done in the past few years?

R. F. HARRINGTON: It seems to me what Dr. Moldenke is attempting to do in this paper of his is to bring the facts of the situation before us as he views them and to offer constructive criticism as to ways and means of getting at this problem of, I will call it, not poorer pig iron today, but discrepancies that might occur between one brand of pig iron manufactured from one particular furnace and another iron produced in another part of the country. I believe there is something to his point of view. I believe that there are pig irons today that contribute different characteristics to the final melt. One phase that has again been forcibly brought to my attention has been the question of a particular pig iron tending to produce in castings a certain amount of interior shrink or total over-all contraction greater than other pig irons, and when that particular pig iron was removed, all other elements, mind you, being constant, the trouble disappeared.

Coming down on the train from Boston with some half dozen foundrymen, two of them were discussing this matter and both men picked out a particular brand of pig iron and said that they were having trouble with it. Neither man had discussed the subject before with each other. One of the men was operating his plant under the direction of a very able metallurgist whom we know in the East and whom we all respect, and when that particular pig iron was reduced from 25 per cent to 10 per cent in the mixture, or eliminated entirely the shrink problem disappeared. So there does seem to be evidence that furnaces operating under particular conditions may produce an iron that is unfavorable so far as its effect on the final mixture is concerned.

Now, as to how we are going to remedy that particular situation, it seems to me that as in this instance, where this one iron apparently was giving trouble in more than one foundry, if that iron, or portions of it, could have been submitted to some arbitrary board to look over and test out in a practical way, we might have arrived at some conclusion. I believe there is every evidence to warrant serious consideration of this blast furnace problem and the foundryman's problem in connection with the use of pig iron.

R. S. MACPHERRAN: The quality of pig iron should be sharply distinguished from its properties. The only quality specified today, however, is the quality of making good castings. The subject particularly under discussion is the effect on the pig iron produced by adding borings and turnings (referred to as "scrap") to the blast furnace burden. I will at once say concerning this that I have no fixed opinion. I do not, in fact, see how I could have one; I have no basis on which to form it. I have never seen a car of pig iron where I was sure that scrap was not a part of the furnace charge, nor have I ever seen a car of iron where I was sure that it was.

I have often gone to agents or employees of furnaces and asked about their practice. The answers are usually evasive or conflicting; I never

could understand why such a mystery is usually made of it. If the practice of adding scrap is good, why keep it secret? If bad, why not stop it?

The opinion of the average foundryman as to the effect of adding borings and turnings to the charge is often colored by his own experience. Many a foundryman has shoveled loose borings, etc., into his cupola in the afternoon and woke the next morning to the saddest day of his life. Whenever the use of borings is mentioned, his mind naturally reverts to this and he feels suspicious of its use even in the blast furnace. Whether this suspicion is justified or not, some of us feel the question is worthy of consideration and investigation.

Our Sub-Committee on Pig Iron of the A. F. A. Committee on Cast Iron has been endeavoring, therefore, to find some furnace which would be run alternately with and without scrap in the charge. The resulting pig iron would be given comparative physical tests and would be shipped to foundries for actual use under foundry conditions. I may say that a test of this kind is now being run, but not under the auspices of the committee, where pig iron is made with various amounts of scrap and the pig iron is being tested.

With our present knowledge of pig iron, it may be difficult to make a satisfactory comparative test and it may be some time before such is worked out. The committee will welcome any suggestions from those interested. Quality and uniformity of pig iron are both requisite for the production of high-grade castings. Anything, therefore, which might promote irregular working of the furnace, with consequent increased production of off iron, is of interest to us. Has scrap this effect on blast furnace operation? This is put as a question which, as foundrymen, we have no way of answering. The tendency is constantly toward higher grade castings, with more severe service. If we expect to meet foreign competition, this tendency must be met.

We realize that this question is a blast furnace operators' proposition and that without their help this question will never be settled. There is no intention of finding fault with them or of criticizing their operation, but merely the wish to work with them to our common good. We feel that mutual confidence and co-operation are needed on both sides.

J. T. MacKenzie: I am one of the men, I think, who is favorably inclined to the use of scrap in the blast furnace. My prejudice—that is all I think any of us have—lies the other way. Of the three largest producers of pig iron in the Birmingham District, one furnace uses virgin ore without any scrap, one furnace uses a very small amount of scrap and one furnace runs regularly with 10 to 15 per cent scrap. Now, some of the foundries, on some classes of work, seem to get along better with the virgin ore pig iron. In the cast iron pipe, particularly pressure pipe, we find that up as high as 25 per cent steel scrap does not seem to affect the pig iron at all, that particular furnace using the scrap is the one that gives us our best pig iron for cast iron pipe. I don't know whether that is a coincident or a result. So far we have been able to tell by watch-

ing the workings of this blast furnace that percentage of scrap causes no irregularities in its operation, but I am not able to say anything about turnings and borings because they use very little, most of it is pretty good scrap.

It does seem to me, though, that the blast furnace men lay themselves open to criticism if they don't take hold now, when the foundry industry is ready for it, and perform some conclusive set of experiments in co-operation with the foundrymen themselves to determine once and for all whether this thing has any bearing on the quality of the pig iron. If the addition of scrap and borings to the furnace causes the furnace to run irregularly, then we should look more to irregular operation of the blast furnace and not to the use of scrap. We do know that when a blast furnace is hanging and slipping, we get very poor pig iron, and that the hardness and difficulty of machining is out of all proportion to the chemical analysis of the iron. But whether that would be accentuated or not by the addition of scrap in one form or the other, I don't know and I don't think anybody can say. I know that the furnaces working on nothing but ore give bad pig iron when they are slipping, so if the scrap merely made them slip twice as often, it would seem to be a poor thing for the blast furnace men to use, and I assume from the continued use of borings that they don't have particular trouble in their operation.

Another thing we can't put borings in the cupola. What are we going to do with them? If we can get five or six dollars a ton for borings from the blast furnace man and he melts them down under good blast furnace conditions and sells them to us as good pig iron, that certainly will be far better than our trying to briquette them or put them in cans or stovepipes or anything else and melt them with a high loss in the cupola.

I made a heat of some ten tons of borings one time in gallon cans which were pressed together, not soldered, and took particular pains to place those cans in the cupola bottom down, with the lids that had been cut for the extraction of the fruit pressed down on them, and I found that I got $17.50 worth of pig iron for $22. So if we had gone on and sold the borings to the blast furnace in the first place, we would have been a whole lot better off.

I want to reiterate that my prejudice is in favor of the use of that material in the blast furnace, so that we can keep it out of the cupolas, and if we can prove that that is not detrimental to the pig iron, I think it certainly should be done.

J. W. Bolton: For some 25 or 30 years we have been talking about mysterious inherent qualities in pig iron. Perhaps they do exist, perhaps they do not. Today, Mr. MacPherran has outlined very briefly to us some work that is to be undertaken to really determine if there is anything to these hypotheses. I think in that matter we all have opinions, but in this laying out of a program for work we have one of the first real, honest, progressive steps we have had along this line.

Now, I have opinions just the same as the rest of you, but I will be

very frank, I do not know very much about pig iron and, therefore, I am going to leave it to those who do, or those who later find out, to talk to you about it.

D. L. WARD: I did not hear all of Dr. Moldenke's paper which has just been read, but a few days ago I read a paper that he apparently presented recently in New York, which I imagine is the same paper he has read here today. I was astonished to learn that Dr. Moldenke had made statements in his paper that unquestionably are his opinions but were put to you as established facts. Anyone with even the slightest knowledge of the development in this country of blast furnace operations knows that pig iron produced today is being made under immeasurably better conditions and under more regular and uniform operations than ever before and especially so when compared with the days of Dr. Moldenke would lead you to believe pig iron was far superior to what is produced today.

You will find that the blast furnace man is perfectly willing to cooperate with you to determine just what, if any, trouble you are having from pig iron, but, unquestionably, what you gentlemen want to know are the facts involved and you certainly have not had facts represented to you.

It is commonly known among blast furnace men that the subject of reactions that take place in a blast furnace seem to appeal to many who have some knowledge of chemistry. It is also known among blast furnace men that when chemists attempt to discuss the reactions that take place in blast furnaces, that their written discussions are not borne out by what we know to be the facts unless their knowledge of chemistry is accompanied by some actual experience with blast furnaces.

I believe it will be much better to go into this subject in a thorough manner and have established facts presented to you instead of my opinions or the opinions of someone else, but at the present I can disabuse your minds of at least some of the statements Dr. Moldenke has made to you. One of these statements is that you have been led to believe your pig iron is not as good as it formerly was because blast furnaces have been making more pig iron today than in the "good old days" and that one of the reasons for this is harder pushing of the furnaces, that is, harder blowing of the furnaces. This statement is absolutely not so and you can readily verify this by obtaining a history of the blast furnaces in this country.

The increased tonnage has been obtained in a very large part and almost entirely by improved lines or construction of the furnaces and the improved selection and grading of raw materials; particularly in the coke which is now almost entirely made for blast furnaces in by-product coke ovens.

Anyone at all familiar with blast furnace operations knows that the most dominating factor in operating a blast furnace is the fuel supply and would also know that the fuel supply for furnaces today, where the by-product coke plant is located adjacent to the blast furnaces is immeasurably more uniform than when blast furnaces were served by beehive coke ovens. For instance, most blast furnaces today in obtaining their coal supply for

their coke, obtain coal out of one mine which goes to their by-product ovens and then to their furnaces every day in the year, whereas, in the days Dr. Moldenke speaks of, nearly all blast furnaces were supplied with coke from miscellaneous beehive coke ovens, which were charged with miscellaneous coals.

This is known to be so important to blast furnace men that it is obvious to any experienced furnace man that this most important factor is one that is unknown to Dr. Moldenke or he would have made mention of it in his paper.

Undoubtedly, you foundrymen are aware of the importance of regularity of fuel and I know that if you will investigate this aspect of blast furnace operations, you will find it has had most careful attention. It is careful attention to fuel supply and other details incident to successful operations of blast furnaces that has brought about the increased tonnage and not the harder blowing that Dr. Moldenke states to you.

We have looked into the records and know that the charcoal furnaces used from 50 per cent to 100 per cent more wind in proportion to their capacity than the coke furnaces of today and the records will also show when coke was first used that proportionately more wind was blown, so that insofar as quality of pig iron is concerned there is absolutely no fact in the statement that furnaces are being blown harder today than they were formerly.

Another point in Dr. Moldenke's paper that I should like to answer, is his reference to scrap and the use of scrap in blast furnaces being another cause for deterioration in the quality of pig iron. A comparison of furnace operations, I believe, would show that the amount of scrap used in blast furnaces today is no greater, if as great, as when iron was cast in the sand, back in the "good old days" you have been told about.

One of the principal reasons that you foundrymen found yourselves forced to use chilled cast pig iron as made today was the result of the furnace man endeavoring to get away from making so much scrap, all of which had to be charged back into the furnaces.

I, personally, went through the transition period, from sand to chilled iron and I know how much trouble it was to get the foundryman to accept chilled iron, but it was necessary for the blast furnace man to make this change in order to keep pace with progress.

In addition to the large amount of scrap that was made by the blast furnaces when producing sand cast iron, all of which was charged back into the furnaces, the off iron was also charged back. We frequently had as high as 30 per cent off iron as an average over a year, whereas, today it is not at all uncommon for furnaces to operate year in and year out with 2 per cent off iron that is over .05 in sulphur. This should not only give you a very clear idea of the decreased amount of scrap the furnaces are called upon to remelt today from their own production as compared with the "good old days," but should also make clear to you the great improvement in uniformity of furnace operations and particularly as to uniformity of

temperature in the blast furnaces, as temperature control in the blast furnace is directly reflected by the sulphur content of the iron produced.

I know of very few furnaces, if any, today, that are using over 10 per cent of scrap and you may be assured that this scrap is carefully selected and checked before being used.

Pig iron is being sold on analysis today and all furnaces have well equipped laboratories for the analysis of, not only the finished pig iron, but all raw materials incident to the production of pig iron. Nearly all foundries are similarly equipped or have access to laboratories so that it would be the height of folly for a furnace man to use material containing elements objected to by the foundryman, as analysis would clearly and easily indicate the presence of such elements in the iron received by you.

Mention is also made by Dr. Moldenke of oxygen in pig iron or occluded gas. If he were at all familiar with blast furnace construction and the relation of the wind blown to the furnace areas exposed to the incoming blast, he would know that there is a great deal less likelihood of oxidizing iron than there ever was before.

It may be possible that Dr. Moldenke knows there is oxygen in pig iron but you may be assured that if it is present, it is in a great deal lesser amount than it was back in the "good old days."

A check-up of the furnaces in this country will show that while the production has been very materially increased per 100 cubic feet of furnace capacity, the wind that is blown in the furnaces has very materially decreased.

If you will get some of the figures of the blast furnaces as to how much wind is going into them, and the area to which the wind is exposed, you will readily see that the possibilities of oxidation are about 75 per cent less than they were when you were getting pig iron out of the small furnaces.

I do not mean to say that there is no oxygen in pig iron, and while we have heard of this theory from chemists for the last 25 years, it must be remembered that blast furnace operations are deoxidizing ones, which is almost the exact opposite of cupola operations which are largely oxidizing. Claims are made for it and some people think, and the Bureau of Standards feel, that they now have a method of analysis that is reliable, but it is a difficult determination to make. If oxygen is present, you are getting a great deal less of it today than you ever did in the "good old days" and you can be absolutely certain of that.

Dr. Moldenke's paper intimates throughout, that the blast furnace man is paying no attention to quality and has little interest in how successful his customer may be in using his product. This is certainly not in keeping with present day business methods and I will not attempt to defend the business methods of the blast furnace man, as they do not need defense. In fact, I am certain that you will find the blast furnace man perfectly willing to cooperate with you in every way possible toward helping you solve any of your problems.

I would rather have confined my comments to you along somewhat other lines, but whether you accept it or not, my criticisms of Dr. Moldenke's statements to you are made in a sincere attempt to prevent your being misled.

It is obvious to anyone familiar with the improvement of blast furnace operations in this country, that when Dr. Moldenke lays all of your troubles to quality of pig iron, he is evading his own responsibility, which as I understand it, is to help you foundrymen to make satisfactory castings from the materials which you have at hand.

Certainly condemning pig iron in general is going to be of little, if any, assistance to you, at least on the grounds claimed, as I can assure you that the iron being made in the large furnaces today is much more regular than that which was made back in the "good old days." I also doubt whether the foundrymen could afford to pay the exceedingly high price for pig iron that would be necessary if pig iron were again made in small quantities, which would, of course be accompanied with exceedingly high cost of manufacture and a correspondingly high selling price. While I do not know, I imagine the same thing holds true in the foundry business, that is, you could not afford to go back to the small daily tonnages in the foundry that prevailed years ago.

The blast furnace man has attempted to keep the cost of pig iron to you commensurate with the times and with the progress that business has made in this country in general, just as you foundrymen have, and I can assure you the progress made in blast furnace production and cost has been attained by the most careful attention to quality. Any other policy would be, as previously stated, outside the pale of present day methods of conducting business.

CHAIRMAN R. H. SWEETSER: I think it will be very enlightening to see these figures that have been prepared from authenticated records of charcoal blast furnaces and the old anthracite furnaces and the coke furnaces.

D. L. WARD: Our time was so limited we could not tabulate the figures in a manner that we thought would be satisfactory to hand in. In fact we feel that these figures should be compiled in some way under the direction of the foundrymen so that they would be certain they are getting facts, and I am confident their Association will have little trouble in obtaining these figures.

I will give you, however, the figures we hastily compiled and which I am certain can be verified. These figures are as follows: Old records of blast furnace operations show the amount of air blown into a small furnace was from 90 cubic feet per minute to 400 cubic feet per minute per square foot of hearth area. There seemed to be no standard in this respect at that time, while the amount of wind blown in blast furnaces today is quite well standardized in that respect, that is, all furnace men know today that a furnace of a certain size gets very close to a certain amount of wind.

Comparing the furnaces of today against this range of 90 cubic feet to 400 cubic feet per minute per square foot of hearth area, we find eight of the largest furnaces in the Chicago district are all blowing practically the same, which is approximately 163 cubic feet per minute, per square foot of hearth area.

Comparing these large furnaces with their practices in 1910, shows that whereas the cubic feet of wind per minute per square foot of hearth area is 163, it was 250 in 1910 on the same furnaces. This very clearly indicates that while the tonnages have materially increased, the amount of wind has very materially decreased, which is directly in contradiction with the statements which have been made to you. These figures also clearly indicate the lesser likelihood of oxidation of iron by being subjected to the blast entering the blast furnaces.

MEMBER: But they are all steel works furnaces, aren't they?

D. L. WARD: No, some of the larger furnaces in the country today are merchant furnaces. This is an average of some steel mill furnaces and some merchant furnaces.

MEMBER: What percentage of each?

D. L. WARD: If I remember correctly, there were about one-half merchant furnaces and about one-half steel mill furnaces. However, I can give you some figures on strictly merchant furnaces, as follows: Since 1910 the pig iron produced in these furnaces has increased 83 per cent, while the amount of wind blown into these furnaces per 100 cubic feet capacity has decreased 15 per cent and the cubic feet of air blown per minute per square foot of hearth area has been reduced 44 per cent.

These figures I am giving you were taken at random and were not selected furnaces, by any means. Any of you foundrymen can obtain these figures from furnace men without any difficulty, or from any of the engineers who build blast furnaces.

You will find, I am certain, that a comparison of the amount of wind blown in the blast furnaces today, with the amount of wind blown years ago, will show universally, throughout the country, a very material decrease in proportion to the size of the furnaces. You may wonder about that, but the entire increase in production that has come on these furnaces and particularly the two merchant furnaces mentioned, has been due to nothing else than improving the lines of the furnaces, careful selection of the raw materials and careful attention to their distribution as charged into the furnaces, together with a very great improvement in the quality of coke used.

J. A. MURPHY: One of the most descriptive words in the English language that I can think of to describe the pig iron that we have found we have been getting for at least eight years is that it is raw. That is the best descriptive word that I can apply to it. Now, it might be said on the part of blast furnaces, their advocates and agents, that the quality of pig iron has deteriorated on account of the foundrymen's buying prices, but the greater part of this deterioration took place when the blast furnaces got their own price and we had to take what they gave us.

Now, the attention of a good many blast furnaces has been called to this raw pig iron because it is highly oxygenated and probably more scrap used in the furnace than there ought to be, and less coke, but they have practically told you, "Well, you have got the pig iron, use it."

Now, instead of all this research that we are trying to go into, what we need is a little more common honesty, and if the blast furnaces will put in some more coke, add a little fuel to the fire—and a blast furnace won't work on an empty stomach any more than an army will fight on one—you will get better pig iron and you will eliminate a whole lot of foundry troubles.

About eight years ago I saw some of the most mystifying blemishes on castings that I ever saw and I didn't recognize them. I called in everybody who had made any claim to knowing anything about it to help me out and set me right, and they all failed. I heard it said a few minutes ago that the days of the charcoal iron were about gone, but those particular mystifying blemishes that occurred then and are occurring today in various foundries can only be remedied through the generous use of charcoal iron in the mixture.

Get into the higher classes of work, into the machine tool work and engine work, where castings are ground and polished, and even today where some charcoal iron is not used in the mixture those same mystifying blemishes that I saw back in 1919, 1920 and 1921 occur.

I don't think that the use of some kinds of scrap in the blast furnace is a detriment to the resulting pig iron, but there is scrap and scrap. And one of the problems of today is to get rid of the old auto scrap. It is being cut up in suitable sizes for the blast furnace to pack away in the maw of the furnace, and you have in that class of stuff vanadium, titanium, and molybdenum and such. While I don't know what most of these metals do to cast iron, I know for a positive fact from experiments that I made years ago on vanadium and titanium and these other elements which were advertised to the skies some years ago as being of benefit, I have found that they were absolutely detrimental to cast iron. Neither one of those two metals will work with a grade of cast iron that has free carbon present. Now, just what they do is a long story to tell, but, at any rate, I am sure that that is what is partly wrong with the blast furnaces. They are using up this cheaper scrap. I don't think borings are doing any damage; I have used them for years and never found them anything but a benefit. It is the kind of scrap they are using, the cheap fuel, and too little of it, that is causing all our troubles with pig iron today.

CHAIRMAN R. H. SWEETSER: We will listen to the paper by David McLain of Milwaukee on "An Expression of Views on the Use of Iron Scrap in the Blast Furnace." Mr. McLain has put his views into print and we will be very glad to have him present them here verbally.

This paper appears on page 319.

C. C. KAWIN: The question of making an oxygen and nitrogen determination in a laboratory is a very difficult one. There are very few laboratories equipped to handle ordinary analyses accurately, and I have been in laboratory work for 25 years commercially and 37 years all told, through blast furnace practice and steel mill work, where they did things right, and from our position we have no axe to grind with the foundrymen; we have done very well, but there is no one going to pay for oxygen or nitrogen determinations or metallographic tests that I know of in the foundry business, in the general jobbing business, today; they cannot afford to and they are not going to, and you will kid yourself if you work along those lines.

R. H. WATSON: I have been superintendent of several merchant blast furnaces. For a long number of years I was superintendent of the Detroit Iron and Steel Company, and one of the largest customers we had there was the Ford Motor Company, which purchased from 75,000 to 125,000 tons of iron a year. In the operation of the blast furnaces of the Detroit Iron and Steel Company, we used only the furnace runner scrap, which amounted to about 1/10 of one per cent of the weight of the total charge of ore, and no outside scrap was used. These blast furnaces produced about 700 tons of merchant pig iron a day.

I was made superintendent of the blast furnaces of the Ford Motor Company and was at this plant for a year before their blast furnaces were put into operation. During this year I had the opportunity of observing the use in the cupolas of the iron made at the Detroit Iron and Steel Company and this iron, as I have said before, was made without the use of scrap.

When I put the Ford blast furnaces into blast, I found that we had a large amount of cast iron borings on hand. I used 25 per cent of them in the mixture. I would have used 100 per cent if I could have handled them. However, I found that the way the borings were charged into the blast furnace made a difference in the resulting pig. If we put 4,000 or 6,000 pounds of borings on each charge of 24,000 pounds of ore we found that this threw our stock distribution off, and the furnace did not work well. So instead of charging that way I put in, at regularly spaced intervals, a whole charge of 24,000 pounds of borings. Under this method of charging the furnace worked well, it did not slip and our silicons were uniform. We used the pig iron made this way, both in the direct casting, the metal being taken hot from the blast furnaces to the foundry, and also in the machine cast pigs charged in the ordinary manner into cupolas.

In using this iron in the foundry we had no increase in the amount of scrap in the castings, and I can frankly say that there was no trouble from using it any more than from using the iron made without scrap.

I remember one time in a certain foundry they raised a row because there were cracks in the apron on the motor casting, and we investigated it. They said it came from the iron. I watched for several days in the foundry and it was from the iron. You know the way they clean the

cylinders as they come down, the man has a little hammer and he raps in this way and knocks what dirt is in the bore out, and if he doesn't knock it all out, he gets fired. I watched this for several days and I saw a fellow had an eight-pound sledge hidden under his bench, and he would take this out and bang it and along would come the next one and he would hit it with a sledge hammer and of course it had a crack in it, and so far as producing cracks in the iron is concerned, that is the way they were produced, and not by using scrap in the blast furnace mixture.

Dr. Moldenke brought up the fact that when a number of us were a good deal younger than we are today the foundrymen had fracture tests; that they then became more enlightened and went to analyses. You know, they should have brought some of that fracture test along with the analyses; a little visual inspection, a little look in the face, is a pretty good bet, and I venture to say here that it will come along in this way.

Now, you all have variations in your silicons, in your iron. That comes from the fact that no furnace, however good, will work evenly, but you will have a higher silicon in this ladle and a lower silicon in that ladle. Now, they have gotten away from that by putting in a 100-ton ladle, so each little pig, approximately, has the same squeal as any other little pig.

Now, gentlemen, they are going to go a step further. It has been my experience that in the manufacture of gray iron castings, the casting temperature of the pig iron from the blast furnace has a lot to do with the successful melting of it in the cupola. That is where this little fracture test has a lot to tell you. Now you have the silicon averaging the same, I venture to say that you are going to ask the blast furnace men for the temperature of the cast from which your iron comes and a photomicrograph from that little sample that goes with it, and I think a lot of your pig iron troubles will be over with.

DR. R. MOLDENKE: I am frank to admit I do not know if I want to say anything at all after I heard our friend here talk about their fine blast furnaces. What is the use of talking any more about it? You are all getting magnificent iron; so go home and use it!

Now, I personally have never objected to a blast furnace using borings. Borings get out in the open air and rust outside and inside, and when they get into the blast furnace they are almost ore. What is wrong about that? Nothing at all. I have no objection to your using borings. Of course, I don't like to see you use 25% charges. But what I do object to is this common scrap, remelted stove plate scrap, pipe scrap, all of that shoved through the blast furnace to the extent of 50 or 60%, and then charge foundry pig iron prices for it.

If you put a good piece of steel in the blast furnace, that is fine; but when you take scrap that has been remelted and remelted in the cupola and put through the blast furnace, much of it goes through without any change except in the sulphur; I am pretty sure that most of the sulphur will be taken out, but the oxidation stays.

I can only say this: the investigation is going to be a very difficult one. I don't know whether we will arrive at any results at all. I do admit that what you say is true; we are going to have to use this material, there is no getting away from that. Fortunately, there is a way of using it, and that was brought out in the Detroit Convention by Professor Piwowarsky through his idea of a high degree of superheat. That will deoxidize the iron and give you the magnificent strengths, etc.

Now, then, we speak about there being no cause for complaint about pig iron. If that is so, why did the German Foundrymen's Association appoint a pig iron commission over there to study this very thing? On account of having the same trouble as we are having over here, and for no other reason. The furnaces had been using scrap heavily too.

DAVID EVANS: First I want to compliment Mr. Robert Watson, not only on the highly intelligent quality of his remarks but their practical character, and what I got from what he said was this: that it doesn't make any difference whether you use scrap iron in your blast furnace or not, it depends entirely on the method of using it, just as the question of whether you are going to get good castings or not depends entirely on what sort of practice you use in the foundry.

Very frequently we put 95 per cent of our consideration on inanimate objects and overlook the personal element, such as the operation of a furnace. I cannot speak with any particular degree of authority because I never operated one, but I have been studying pig iron for something over thirty years and I have noticed that the operation of the furnace has a great deal more to do with the quality of your iron than the materials that you use. A good foundryman will make good castings out of what he has to work with very frequently, at least, a good foundryman can take rather inferior metals and get very good results; and a poor foundryman cannot make castings with the very best materials to be had.

Now, as to the deterioration in quality, I can't agree to that at all. I know that in 1914 when there was a rather light demand for pig iron, our furnace superintendent at Birmingham began experimenting with shortening the blowing time on stoves. With only one stack out of two in operation, he had more stove capacity to work with. The result was that by shortening the blowing time, he kept his temperatures uniform, he produced a higher quality of pig iron, and we haven't had a complaint. I haven't had a complaint on the pig iron I have sold in so many years I can't remember how long ago it was.

MEMBER: We have been talking here about the good old iron and the iron we get today. Well, I guess it is apparent that I don't know very much about the good old iron, but we do know that the demand for quality in our castings today is getting stiffer and harder to meet. That has happened within my few years, and I think from the machines that were made when the so-called good old iron was on the market, a number of which I have seen, the castings in those machines wouldn't go today

with what people are demanding. The grain is open, and if you look into the slots of the tables you will see a lot of shrinkage.

I think our greatest trouble today is to get an iron that is consistent. In other words, we can take a pattern, we can mount it with a permanent gate and a permanent feeder or riser, and that pattern may be run four or five times within a year and the castings are good. The sixth time that same pattern comes in, we will get a bunch of shrinks, probably external, sometimes internal, in that casting, although neither the gate nor the riser is changed and, as far as we can tell, the analysis is the same and the operation of our cupola is the same. I think that the biggest problem that the foundryman has today is to get consistent material to work with. If we know the limitation of the iron, we can gate it, we can put a riser on it to take care of that limitation, but we don't have consistent iron and we get openings of grain and hard castings and shrinkage due to the variation in pig iron. If we could get a consistent result from the blast furnaces, I think that would do more to overcome our present problem than anything else.

V. W. AUBEL: Without going into the metallurgy or the metallography of cast iron, of which we have heard quite a bit, as a blast furnace operator, I am primarily interested in what the factors are that make good pig iron. Now, these factors happen to involve two or three things about the operation of a furnace. It is either in the raw materials which go into the furnace or in the operation of that furnace or in the preparation of the product for sale.

Now, going into the furnace, of course, you have your coke and your ore and your limestone and perhaps scrap. Now, the coke. The blast furnace operator who has control of his coke source and probably also control of his coal mixtures, so that he can regulate the preparation of that coke for the furnace, has something that is bound to reflect in the pig iron. The coke quality must be reflected in the pig iron.

The quality and uniformity of the coke will influence the quality of the pig iron to the extent that it influences the normal operation of the furnace and the regular operation of the furnace. Irregular coke will make irregular furnace operation. If you can get regular furnace operation, you have gone a long way towards getting good pig iron. You will all agree to that, I think.

A great deal has been said about scrap. I want to say a little about ores. Isn't it true that economic conditions over the last, say, ten years or less than that, have compelled furnaces to get their ores from a great many different sources? In other words, in the old days which you all talk about, very often the furnace was sitting right up alongside of the ore mine and that furnace used one grade of ore all the time and that one grade of ore was never changed or mixed with any other grade. Now, today some furnaces must draw from a great many different sources for their raw material, they have to draw both hematite ores and magnetite ores and sintered ores and all sorts of things like that, including probably some cinders or synthetic material of that kind which is used for the iron content.

Now, I think that some attention in furnace operation should be given to, and some account taken of, the relative rate of reduction of the different ores that are in the furnace burden. That may have some effect on the qualities of the pig iron. Personally, I would want in my furnace burden an all hematite mixture or an all magnetite mixture or an all sintered ore mixture or something like that. I don't think it is fair to expect a furnace to take a mixed burden of part hematite, part magnetite and part sintered ores. This difference in the relative rate of reduction may have some effect on the quality of the pig produced.

In regard to the scrap, I think furnace men will all agree that scrap should be sorted, it should be inspected very thoroughly chemically, because if there are elements in the scrap that find their way into the pig iron, such as the precious metals, vanadium, titanium and things like that that you don't want there, if it is in the scrap, it is going to be in the pig iron.

In the preparation of the product for sale, the furnace operator must be careful and see that it is thoroughly separated from the slag, that no dirt or foreign material gets into the pig, and probably have all the excess carbon or graphite as we call it, kish as the foundryman usually calls it, skimmed off the metal to give a nice, clean pig. Also, care should probably be taken in the cooling of that iron on the pig machine. The cooling may set up conditions in the pig if it is cooled too quickly or not quickly enough, which change the relation between the combined and the graphitic carbon, or set up internal shrinkage strains or cracks in the pig. I think those things should all be considered in getting good quality pig iron.

Aside from the metallurgical or the metallographical side of the question, that, as furnace operators, we want to know what the factors are that affect the quality of the pig iron, and in so far as we are able to do it, we want to control these factors.

G. A. T. Long: I personally feel that the pig iron is better today than it was in the "good old days," and I have come along from the "good old days." But the foundryman's conditions have changed somewhat. I venture to say that there are not three foundrymen here whom you will find using the same air in the same size cupolas. You will find that it ranges from, on a 58 to 60 or 72-inch cupola, 4,000 cubic feet up to 11,000 cubic feet per minute. I believe the point that we are looking for first of all is to standardize the proper number of cubic feet of air per minute. A cupola run first with high and then low pressure will give two different physical structures to your metal, while it won't change your analysis a great deal. I can't see how a man can keep out of trouble when he is away from standard and I have always been a great believer in getting down to standards and measuring the air. I venture to say that not five per cent of the foundrymen today have volume meters or can tell you how much air is blown into their cupolas.

Another point. One will have a small tuyere, and the other a large tuyere, and until the foundrymen as a whole will go to work and get a

standard out for cupola practice, we are not going to get anywhere with our pig iron.

F. W. BAUER: This committee ought to be given all the encouragement possible. When I think back a few years along with Dr. Moldenke, as he says, this has been a mooted question ever since 1902 before this association. It ought to be solved now, if ever.

In the first place, pig iron is a raw material; nobody has referred to that particular point. It is a raw material which is given to the foundryman to be melted with other material, various kinds of fuel, various conditions of pressure, the amount of air and all that, and yet we have an idea that pig iron might be standardized to a point where it would overcome or prevent most of the foundryman's troubles.

Do you think that 25 years ago with the pig iron we made at that time in sand cast pigs that these large automobile foundries, one I have in mind running three to four hundred tons per day of cylinders alone to very accurate and close specifications, could operate with that pig iron on less than a three per cent foundry loss, which they are doing today? And then somebody has the nerve to get up and say that the pig iron is worse today and that we are not making any strides! I don't believe that is true. I am not holding any brief for the foundryman or the pig iron producers either, but take the facts and think what we have done in the production of pig iron in this country in 25 or 30 years. Think of the Ford Motor Company, Packard and other automobile companies, and what they have accomplished by the use of cast iron in cylinder blocks, heads, etc. I am convinced that we owe much to the improved methods in the foundry and better materials, including pig iron. I would like to make this suggestion to the committee, that when they go into it, classify your pig irons, take irons that you know are made from all ore, whatever tests you are going to devise, if you can devise them, make your comparisons between those irons, then make your comparisons with irons, if they have scrap, but don't make your comparisons with iron with scrap and without scrap, because that will get you no place.

The foundry that is making such a fine record on automobile work has told me repeatedly that they prefer a pig iron that has scrap in it. This is contrary to the statements that have been made here about the relative value of pig iron made from all ore and iron made with a percentage of scrap borings added to ore. You must admit there is some virtue in such pig iron that is used in automobile cylinders and it ought to make equally good cast iron pipe or brake shoes. When scrap borings are introduced in a burden making pig iron there should be care to exclude any alloy metals such as chromium, vanadium, etc., unless it is desired to produce pig iron with these elements specified. The tendency to reduce the carbon in the pig iron and consequently in the casting itself is probably helping the cylinder to meet the duty demanded of it today, and pig iron can share in credit for the high grade castings made today.

H. B. SWAN: It seems to me that many times when we go through phases of troubles in the foundry and we check up our practice, check it up as in many cases by all the methods of control and checking that we know how to use, we still find that we have these troubles, even when the analyses check up all right, the Brinell hardness, and your metallographic study and everything point to the fact that you are all right. Still the machine shop will tell you that your iron wears out their tools and you have unusual internal shrinkage, cracks and numerous other things for which it is difficult to find the remedy.

It seems to me that what the committee needs in the way of suggestions is, what is good pig iron? What are you going to use as a measuring stick? What are we going to call standard pig iron? And until we have that standard, the committee, it seems to me, is going to work more or less in the dark, because it may be all right to use borings and scrap and steel and to get good pig iron, but the point that has stayed in my mind all the time that I have spent on the committee is, how are we going to get a standard for 100 per cent pig iron? I believe that the committee needs all the co-operation possible from the various members of the association in this way. For example, when they run across carloads of pig iron that show unusual results and are giving trouble, if those conditions could be fully checked and samples of that pig iron sent to the committee, they might have something to work on. I want to assure you that every member of the committee is giving a good deal of thought to this problem, but they need the help of all of the members of the Association.

WALTER WOOD: I am one of those unfortunate persons who has been told time and time again, "This iron is good enough for cast iron pipe." I take it that when a man says that, he is either ignorant or wishes to make a sale. There is nothing in making pipe that we have to be more careful about than the iron we use. There is one thing, however, about iron which has not been spoken of at this meeting and which seems to me, after all, one of the most difficult things to analyze and understand, and that is what I call the "personality of pig iron." Analysis only gives us a look in. It is like the dressing up of a man. You must go further to understand the "personality of iron." Has it been made out of magnetite ore, has it been made out of hematite, or magnetite that has been sintered? Or it may have been made in a furnace driven in different ways. That personality of pig iron is a thing that I wish the committee would unravel for us, and how far one proportion of a metalloid is influenced by another metalloid in its analysis. In other words, how low in silicon can you go and yet get a very good casting? I have gone very low in silicon and gotten a very good casting. I would like to have the committee tell me why.

There is another thing which the foundrymen are thinking of a great deal and that is the iniquities of sulphur. Now, sulphur is a very bad thing, but in certain circumstances it is a necessary and very useful thing. The same thing applies to almost any of the metalloids that are used, and it is that "personality of pig iron" and the correlation of the metalloids

in pig iron which we haven't yet, so far as I have seen, understood or had anybody explain to us. We hope that at some time or other we will understand those things clearly so we will feel as certain about them as we did about analysis when we gave up fracture in judging pig iron.

R. H. SWEETSER: There has been one expression used here this afternoon and the Chair would like to have that cleared up. I think it is due to the foundrymen as well as to the blast furnace men, and that was the expression used by Dr. Moldenke in regard to 65 per cent scrap in the mixture, and I would like to ask Dr. Moldenke if that was an American practice or a German practice.

DR. R. MOLDENKE: That was German practice.

CHAIRMAN R. H. SWEETSER: I am not familiar with German practice, but I am familiar with American practice and I do not know of any furnace using 65 per cent of scrap in the mixture.

DR. R. MOLDENKE: That was an extreme case.

CHAIRMAN R. H. SWEETSER: Do any of the representatives of the Bureau of Mines or the Bureau of Standards wish to say anything at this time?

E. F. CONE: Before you call on them, I want to explain that you made at the meeting of the American Iron and Steel Institute about two weeks ago the very valuable suggestion to the Papers Committee that a representative of the Government be here at this meeting. We all know that there are a great many differences of opinion as to what the trouble is, if there is any trouble, and what the cause is, and we also know that the American Foundrymen's Association is interested in it, that the American Society for Testing Materials is interested in it, and that the American Institute of Mining Engineers is interested in it. Mr. Sweetser thought that, if a representative of the Government could be here to listen to what was going on, possibly thus Government co-operation could be obtained, so that instead of each one of these organizations doing separate work, the matter could be done by the Government or some agency of the Government; and on that recommendation I, as chairman of the Papers Committee, wrote to the technical secretary of this organization. That was two weeks ago and he took it up with the proper officers of the Foundrymen and Secretary Hoover was notified of that suggestion and plan. I believe it is a good time to make the statement that the response of the Government has been splendid. I wondered whether we would have anyone here, even one man. Instead of one, they have sent two members of the Bureau of Mines, Dr. Herty of the Pittsburgh Station and Mr. Joseph of the Bureau of Mines of Minnesota, both of whom have done and are doing splendid work in research investigations in steel and pig iron, and also a member of the Bureau of Standards, Mr. C. M. Saeger. I think we are very, very fortunate.

CHAIRMAN R. H. SWEETSER: Before calling on Dr. Herty, and since Mr. Cone has made this explanation, I wish to say this further: At a meeting of the Iron and Steel Committee of the American Institute of Mining

and Metallurgical Engineers about three weeks ago Dr. Dorsey A. Lyon, the Chief Metallurgist of the U. S. Bureau of Mines, said, "Why don't you iron and steel men make use of the facilities furnished by the Government?" And he said this, that Secretary Herbert Hoover stood ready at any time to help the iron and steel men, just as the Department of Agriculture helps out the farmers. Here are facilities of the Bureau of Mines and the Bureau of Standards, with trained men who will help us in our problems. But, mind you, the pig iron men and the blast furnace men will have to foot most of the bill, so don't think that we are bringing the Government in here to interfere in any way with business, but the Government has offered its facilities and we are going to ask Dr. Herty if he will explain what some of these facilities may be in the Bureau of Mines.

C. H. HERTY: There is just one thing that I would like to stress first of all. Mr. Sweetser put his finger on it slightly. That is, that if an investigation of the type that is being considered is taken up, I hope that nobody present will expect the thing to be solved in one year or expect that we can cover all the phases of what is in pig iron. That is a tremendous thing to go after and that can't be solved with a five-year program, because it is a very complicated problem. But I do think that the Bureau of Mines and the Bureau of Standards will be very glad to co-operate in this way.

We have some men who are pretty well trained in both plant work and in laboratory work and we have equipment, testing equipment, physical testing, melting furnaces of a good many different types, and we will be very glad to take general supervision of anyone whom the Foundrymen's Association or the Blast Furnace Association could put on this job, we ourselves being under some sort of an advisory board from these different associations. I don't think that the Bureau of Mines wants to tackle this job as a Bureau of Mines problem without the help and advice of the foundrymen and the blast furnace men, just as in the open-hearth work we are doing we have a committee consisting of two open hearth men and two blast furnace men and myself, and we are under the advisement of the Open Hearth Committee of the A. I. M. E. Now, I think if we can work out a scheme whereby the foundrymen and the blast furnace men, for instance, would put up enough money to support a research fellow, we will be very glad to have all the physical testing done and special chemical analyses, such as for oxygen, silicates, any other oxides that are present, and also the special elements which are likely to come into the burden of the blast furnace, through the use of foreign scrap. Furthermore, it will be perfectly possible to take some iron which is off-grade according to the foundry practice, to remelt the iron in some of these induction furnaces and find out just how to make this iron better, and to compare that with iron that is of normal quality.

I think that the way to tackle the thing is not to look for scrap in the blast furnace, because if you start monkeying with two blast furnaces,

one on scrap and one off scrap, you are likely to run for five years and have your research man paid so much and not be anywhere at the end of that time.

What I would suggest to the committee is that this research man, or men, be put on the job in a number of foundries, close enough together so he can get from one to the other, and when the castings begin to go bad, to have the iron that goes into those castings traced. And, furthermore, at the time they are going bad to have him there to watch the cupola operation, which I think is very important, and have records taken at the blast furnaces where you are getting that iron, not just take the iron and then go back to the blast furnace, but keep track of those blast furnaces that are making that iron.

Now, then, when you have found out what the difference is between one iron which may be throwing your castings off and the good irons, then you have something to start back on to the blast furnace. But I don't believe you can go to the blast furnaces and begin to watch them and wait for your poor castings. We did that on one open hearth job and we are still waiting, so we have changed our method of attack altogether.

I am sure that the Bureau will be very glad to get into this work. We are doing work with the blast furnace people, the open hearth people, and I think to be able to get into the foundry end rounds out our scheme of things pretty well.

CHAIRMAN R. H. SWEETSER: Does Mr. Saeger wish to say anything for the Bureau of Standards?

C. M. SAEGER: There is not much that I could add. The Bureau, I am sure, is willing to co-operate with the committee and to do whatever it can ni the line of investigation of this sort.

J. T. MACKENZIE: It seems that the main thing we are up against right now is a test on pig iron or cast iron. It just occurred to me to summarize the number of tests that it will take to establish even in part the properties of such irons as might be accumulated for the purpose.

Of course, you have the analysis. I am quite confident that some of the controversy as to the relative merits of pig iron now and some years ago is due, as some gentleman has said, to the difference in total carbon content. We know that with the hot blast that the carbon has gone up. Even now in England it is nothing uncommon to see analyses of pig irons with 3.2 per cent carbon, whereas nothing like that can be found in America outside of a few cold blast furnaces, whose output is comparatively insignificant.

But even omitting the rare metal analysis, you have the tests necessary to establish the value of the pig iron, first, you might say, the transverse test, with its deflection. I feel that not near enough emphasis is given to a deflection as compared to the load, which is a rough way of determining the so-called modulus of elasticity. You see it stated that a man raised the strength on the test bar from 2,000 pounds to 3,000 pounds and raised the deflection from .30 to .33, and he says that he increased the deflection,

where, as a matter of fact, the deflection was very much decreased, or the modulus of elasticity very much increased, and that iron is a great deal stiffer iron, it is harder to cast, it freezes at a higher temperature than the iron that broke at 2,000 and bent .3 of an inch. That point is certainly not sufficiently emphasized.

Then, too, in the shape of the bending curve there is quite a lot to be learned. You will find that some cast irons bend in almost two intersecting straight lines; others, especially low phosphorus iron, tend to go up very stiffly at first and then bend over a great deal. The higher the phosphorus, the nearer it is to a straight line; the lower the carbon, the nearer it is to a straight line. If you have no autographic machines, you can take readings at every .05 of an inch deflection, read the load, or at every 500-pound load read the deflection, and approximate that.

The tensile strength will have to be determined on these irons in different sections; it will not be enough to cast the pig iron in a half-inch section and determine the tensile strength, nor will it be enough to cast it in one and one-quarter inch section and determine the tensile strength.

The variation in hardness from section to section, which is a reflection of the formation of graphite, will vary with the character of the iron and will not be a function of the physical properties on one bar. It has been found in Germany that by using low carbon irons with sufficiently high silicon to produce the necessary softness for machining purposes, the uniformity of structure in heavy castings can be very materially improved.

Then, there is a question of the shrinkage, both liquid and solid. Do the two irons give the same shrinkage from the pattern and do they at the same pouring temperature require the same size riser, or does one require a much larger riser?

The fluidity must be tested, and we have this morning seen by the paper presented by Monsieur C. Curry that there has been devised a fairly good test. I hope that that test proves absolutely successful. The chill is applicable to some industries. But no testing program that did not at least include those things would satisfy anybody as to the quality of the pig iron, because we hear one man who is making a certain kind of casting having trouble with one pig iron and another man may have perfectly good success with it. The testing program is going to be something tremendous, and I think that the committee would be very greatly overjoyed, you might say, to get the offer here from the Bureau of Mines and the Bureau of Standards.

R. S. MacPhearran: We have had this matter of co-operation of the Bureau of Mines up for the last two or three months and we are very glad to hear that they will help us, though I don't quite agree with Dr. Herty about waiting for troubles from the foundry. We have, though, the following resolution to put before the convention:

"Be It Resolved, that it is the consensus of this assembly that a co-operative study of the effects of varying blast furnace operations on the character of the pig iron made under changing blast furnace conditions and

on the castings made therefrom be conducted under the supervision of the Department of Commerce, with an Advisory Committee consisting of representatives of the National Technical Associations, such as the American Foundrymen's Association, the American Pig Iron Association, the American Institute of Mining and Metallurgical Engineers and the American Society for Testing Materials."

CHAIRMAN R. S. SWEETSER: Are there any remarks? If not, all those in favor of the motion as put, please signify by saying "Aye." Contrary. The motion is carried and will be referred to the A. F. A. Board for approval.

Now, before we adjourn we would like to hear something from Mr. T. L. Joseph, the Superintendent of the Bureau of Mines Station at Minneapolis. Mr. Joseph has been very instrumental and very active in the tests conducted at different blast furnaces, and also at the experimental blast furnace in Minneapolis. Mr. Joseph has been conducting some of these experiments in conjunction with an advisory committee from the different technical societies. Mr. Joseph.

T. L. JOSEPH: I am very glad to have this opportunity of appearing before the members of the American Foundrymen's Association, and there is just one thing that I want to mention. Mr. Sweetser pointed out that I have been doing some work on the blast furnace. I want to say this, that our progress has been very materially aided by the close co-operation we have had from blast furnace men, and I think that that is the attitude of the Bureau of Mines, that if this work is undertaken, they will want to work in the closest co-operation possible with the foundrymen and the blast furnace men. My only regret is that the remarks this afternoon have not been pointed more definitely towards a solution of the problem rather than discussing the problem itself. The last few speakers have made pertinent remarks regarding probable methods of solving the problem. It is going to take the help and co-operation of everyone, and I am sure that the Bureau of Mines will gladly do all it can and that the Bureau of Standards will do likewise.

Now, as to the point of attack, that is going to be an important thing. Dr. Herty pointed out it is going to take five years or probably longer. We have to get a starting point and then build. I have heard probably as many opinions this afternoon as I have heard speakers. We must not have opinions, we want information, we want data, backed up by definite experiments, and that is what the Bureau of Mines and the Bureau of Standards will do if they undertake this problem. However, they will not overlook the very valuable advice and assistance which we know we can get from the foundrymen and the blast furnace men.

MEMBER: I think the statement was made in one paper, or in the discussion afterwards, that the charcoal iron furnaces are driving more air today through the furnace than in the past. I am with the largest producer of charcoal irons in North America, and we are operating today a furnace that was built in 1878, another one in 1884, another one in 1896. All those

furnaces are operating with the same blowing engines, the same temperatures, grade for grade, that we produce. We haven't changed one bit except where a mine would become exhausted and we would have to go to another mine for ore. We have brought our furnaces up to date with the air gun and the opening devices; we put bells on them, and they are modern furnaces, but our practice is exactly the same as it was in 1878 when we started.

Another thing. A statement was made that charcoal iron was a thing of the past. Our operating company is today the only company in the United States doing selective forestry, and if we operate our saw mills as we are doing today, we will be making charcoal iron for the next hundred years, barring forest fires, and we are working along various lines, improving wherever we can.

W. C. McKee: On behalf of several blast furnace operators who I see here, I would like to ask the gentleman who has twice stated that we must use more coke for producing a better pig iron what benefits we may expect to receive from that usage. Now, I have been at this several years and they have always been telling me to use a little less coke. Now, I have been advised here to use some more coke. What are we going to get from that?

J. Murphy: The gentleman I suppose referred to me. In his furnace he will get a higher temperature, and that is quite beneficial, as most of you foundrymen know. The trouble is that the blast furnaces are starting in where the old foundry superintendent left off when he was making six to one several years ago.

T. L. Joseph: I think that perhaps most foundrymen recognize the value of charcoal iron and furnace men know that charcoal iron is made with less carbon per ton of iron than coke iron, so I don't believe that the solution is going to rest altogether in using more coke to make the iron.

Chairman R. H. Sweetser: As a blast furnace man, I perhaps have had as wide an experience as any man here. I don't say that in a boasting way at all, but I have made pig iron with charcoal. I ran the biggest charcoal blast furnace in the world up at the Soo in 1905. I don't think the record of 142 tons a day has ever been beaten. I have also made pig iron with anthracite coal over in the Lehigh Valley and I have made it with different kinds of coke, by-product coke, to my sorrow, when we first started making pig iron with that, with the soft Pocahontas coke and the Connellsville coke, and I want to go on record as saying that a great deal of the reduction in the amount of fuel per pound of pig iron has been in the improvement in the fuel used. For instance, if you take what used to be the standard coke, Connellsville coke, with 12½ per cent ash and 1 per cent sulphur, you would have a certain amount of carbon and you would have to use more coke to take care of the extraneous ash that was in the coke, and that extra coke didn't help heat up your pig iron, it took care of the slag that was made. Now whether or not that extra amount of slag was a good thing for the pig iron, we don't know, perhaps these investigations

will show; but mind you, the temperature of your hearth with your charcoal furnace, the temperature of your hearth with the high ash coke, and the temperature of your hearth with the anthracite was ever so much lower than the temperature of the hearth is as we have it now in a well operated furnace.

Now, how do I know? We have measured. Now, you can't get away from that. We have measured the temperature of the furnace hearth, and it can be done. Your high-grade charcoal iron was made with a very low melting point slag, and today you get in the bottom of your hearth from 2700 to 2800 degrees Fahr., which is ever so much hotter than the hearths of some of the old furnaces, and especially of the charcoal furnace.

I wish someone here would answer Mr. McKee's question. Why it is that we should waste coke in making pig iron?

R. H. WATSON: I would like to tell you something that happened about a year ago. We were making some pig iron for a certain firm that asked for three per cent silicon, manganese .75, sulphur under .050. We had been getting 1200 degrees line temperature on the stove heats. The slag ran 17 per cent alumina, 35 per cent silica, and the balance of it lime, magnesia, sulphur, etc. On this pig iron made with the high blast temperature and coke 2080 pounds per ton of iron produced, we had no complaint. I lost one of the stoves and we had to bring our coke up to 2550 pounds of coke per ton of iron to make this same 3 per cent silicon. The foundry lost every casting made with the 3 per cent silicon, made that way. It is a question of the casting temperature of your iron; it is not a question of the coke, it is a question of reducing your iron in the proper place in your blast furnace, at the proper temperature.

D. L. WARD: Mr. Sweetser, you have several questions and I hope I can remember all of them. I did not intend in my first remarks to be unduly harsh with Dr. Moldenke, I was just interested and wanted to correct him; that is all. But I do not believe that there are any furnaces in this country that have ever approached even 25 per cent of the use of scrap. When I mentioned scrap, I referred to cast iron borings.

While we may not be as honest as we should be, we have not started painting our pig iron yet, anyway.

Every furnace plant has its own laboratories; I know there is not a blast furnace in the country today without its own laboratory, and any well managed furnace, any furnace that is making pig iron on low fuel, which is the result of good management and good thought and experience, is well equipped to analyze all of the material involved; not only that which comes out of the furnace, but that which goes into it. It would be a very foolish thing to use materials which your chemical analysis would show as being objectionable, whether they were objectionable or not; as long as you are buying pig iron and paying your money for it, you are going to pretty well tell what you want, and if one should use material with chromium, vanadium, titanium and that sort of thing, it is bound to appear in the pig iron.

Answering your last question about how you would burn more coke. You could not do it. Blast furnace lines and distribution and the selection of materials, and the almost art, you might say, of making by-product coke today and controlling it, the careful selection of coals, getting coal out of only one mine, as I said, and pulverizing it to a certain positive fineness, putting it through certain sized ovens and taking temperature readings on those ovens every day and then putting this coke into a blast furnace has done more than any other thing to reduce the pounds of coke used per ton of pig iron, as Mr. Sweetser has said.

I could very easily quote any number of cases around the country where the coke consumption has been reduced eight or nine hundred pounds per ton of pig iron, and that is entirely due to the improved furnaces, distribution and quality of fuel.

If the blast furnace man today attempted to burn three, four or five hundred or even eight hundred pounds more coke than he is doing, you foundrymen would get what we know to be cold iron coming out of the blast furnace, the temperature in the blast furnace would be in the wrong place. The very thing that has made for low coke consumption has meant a hot hearth in the blast furnace. Hearth temperatures on the low coke furnaces in this country are higher than they are on high coke furnaces. I know, because I ran blast furnaces back in the "old days" when we burned 2800 to 2900 pounds of coke and we had off iron all the time. We made as high as 35 per cent of iron over .05 in sulphur, which was not at all uncommon, while the principal merchant furnaces will today run all the year round at not more than 2 per cent of iron over .05 in sulphur.

I want to correct what apparently was a misunderstanding of my statement about the charcoal furnace and that you are blowing more wind today. What I said was that the records that we could find of the charcoal furnaces, and, of course, I was going back then to when good pig iron was supposed to be better, all show that the charcoal furnaces were blowing more wind in proportion to their size than the coke blast furnaces of today. That is what I meant. Now, have I made that clear?

MEMBER: I think that may be true of the old-time furnace.

D. L. WARD: That is what I was referring to, back when we all were supposed to be making better pig iron than we are today. When I stated that charcoal iron was a thing of the past, what I meant was that the great bulk of the production is not charcoal iron; forty or fifty million tons of charcoal pig iron a year would be, of course, almost impossible. But I will repeat that there is not any way the blast furnace man knows of that will permit him to use more coke and make better pig iron for you; it is the very thing you do not want. The thing the furnace man has been striving for is the thing that has brought about hot iron in the bottom of the furnace, and that is getting the heat in the furnace down in the lower part of the furnace where it belongs.

ARNOLD LENZ: I have been listening to the discussion pro and con and it seems to go against the blast furnaces. Now, since this resolution is

passed, I think it is our turn to clean our own skirts. I think most of our trouble today in the foundry is due to too strict specifications. I have been very closely connected with the iron business for ten years and we are melting around 1200 tons a day, about 400 tons of malleable and about 800 tons of gray iron in our foundry. I want to make the statement that we have no trouble with pig iron. Now, I think it is largely the foundry practice; if there is a lot of trouble being experienced with pig iron, I think it is up to us to pick the pig iron for the purpose we need it for. There is a lot of pig iron absolutely not fitted for the purpose for which it is used. I couldn't go out and pick any old pig iron for our purpose, but if we go at it and pick the pig iron for the purpose, I think we will eliminate a lot of trouble. I know that the same pig iron that we are using has been used in other shops and they have had a lot of trouble with it, while we experience no trouble from the same types. I think every pound of iron coming out of a cupola should be melted hot and I think a lot of trouble can be avoided in the foundry if they follow that.

I just wanted to say this in favor of the pig iron manufacturers, because they have improved their methods, but they have to do a lot more; they have to do just as much towards better pig iron as we have to do towards better castings, and we have, perhaps, from our own standpoint, forced some of our producers into better practices. For example, we have reduced the range in any car of pig iron to 25 points of silicon. That means, offhand, that if we were using a whole carload in a charge, perhaps we could have quite a variation, but we can only use a few pigs in a charge, consequently we insist that any car coming in must have only a variation of 25 points. Now, that, perhaps, is hard on the furnace, but it is apparently good for us, and it will force the furnace people to improve their practice.

Now, for our malleable iron we can use a bigger variation, we don't put the clamps down quite so tight there, because in the air furnace we use larger charges and you get a mixture out of a larger variation, but you can tell it absolutely in the cupola where you are on close specifications.

One way we have overcome it, as was mentioned a little while ago, we are getting it by getting the furnace people to give us the iron out of one ladle; if they fill a car, to take a fifty-ton ladle or a sixty-ton ladle, and we will take that whole ladle into a car; they run it right into a car and we get that, and our variation is very close. I think it has eliminated a lot of our trouble and I just want to say I think the blast furnace men are coming along very nicely, but there is a lot of difference in the foundry operations.

Dr. Richard Moldenke (Submitted as written closure): It is a difficult matter to do justice to the points brought out by the many men who took part in this general discussion. In voicing the general complaint of foundrymen, both here and abroad, that pig irons have deteriorated in quality, I see that I have "started something" and do not object at all that furnace men are making the best defense they can. That there has been a gradual deterioration in quality in the transition from cold blast

charcoal pig iron to present day hot blast coke iron is to me an undebatable proposition. That present day practice is making more uniform iron, that the furnaces are working better, smoother and more economically is gladly conceded, but uniformity in analysis is quite a thing apart from physical excellence on the part of castings made with pig irons even when the best of foundry practice is followed out. There are doubtless many ways of making bad irons, but of recent years the indiscriminate use of cast iron scrap brought into the furnace yard from the general market has finally reached a stage that has become most discouraging to many foundrymen.

The conflicting opinions of foundry chemists shown throughout the discussion should be taken in connection with the iron centers they serve. The closer to the ore supply, and further away from scrap centers, the more likely that pig irons of good quality will be produced. The arguments in favor of blast furnace practice in such a case must be properly discounted. Again, the arguments of furnace men who quote the huge tonnage increases with less coke used are just as misleading, for they do not mention the fact that the blast temperatures have been practically doubled to do this, and instead of reducing the chances for oxidation of the iron as it drips past the tuyeres, it has been increased. The very best example of this is just in the production of charcoal iron, so much quoted.

The experience of foundrymen who have not noticed any increased difficulties with present day pig irons must also be scrutinized carefully. Where very long castings are made, in which it is obligatory that the molten metal must set before the gates freeze up, otherwise the work tears or at least is full of shrink spots, extra good quality pig irons are entirely out of place, and heavy scrap percentages must be used. I have known the fine, rich, soft irons of the South to be entirely out of place in such cases, and Virginia irons to give best results. Again, the statement is made that good irons give weaker strengths than those made with much scrap. This is true only for the tensile application, but fails where the resilient properties are essential, for these good irons give mighty fine bending results and particularly good shock resistances. Indeed, where resilient quality properties in castings are held at a premium, at least one of the large producers is now paying higher for irons made of "all ore" and no-scrap-in-the-furnace burden. By the way, furnace scrap returned to the furnace is quite a different thing from the scrap originating from cupola melting. The first has been made under reducing conditions, the last under oxidizing influences. I object only to the latter, not the former. In the discussion this should be kept in mind in weighing the arguments.

In looking over the arguments advanced, and knowing the affiliations of most of the men who spoke, fitting their experiences with their practice requirements has not made me withdraw one iota from the presentment I have made. The strenuous efforts of many furnaces to save themselves from disaster by loading their stacks with cast scrap may have relaxed somewhat, but it is not so long ago that I motored past one furnace which

had a higher scrap pile than ore in the yard, and a trainload of scrap was awaiting unloading. Is it a wonder that foundrymen become restive and question where it will lead to? What do the arguments on the excellence of furnace practice become when a prominent journal in reporting on this discussion indicates that while the furnaces gave all manner of proofs of good practice on the floor of the convention, yet in the corridors of the hotel subsequently it was general talk on their part that if the foundrymen would consent to pay better prices they could get better pig irons. In such a light further discussions are useless and I will close mine here.

There remains, then, to my mind, only the solution of the problem of finding a way to test pig irons for quality. The furnace dealing generously with its customers in the matter of producing what was formerly called an "honest" pig iron—that is, one in the making of which no fuel was skimped—is entitled to receive an equally generous price from the foundryman. Making furnace test furnace runs mean little or nothing. They have been tried in Germany by a joint commission of furnace and foundrymen and led to no acceptable conclusions. When the foundrymen will have devised some acceptable method which will evaluate their pig irons, it will be up to the furnaces to produce the goods or enter other than foundry markets, and maybe then the producers of gray iron castings will arrest the decadence of their industry, much of which has come from demands upon their product which they have been unable to cope with—whatever may have been the contributing causes.

The Effects of Chromium and Nickel in Cast Iron

By R. S. Poister,* New York, N. Y.

In their efforts to improve the quality of their castings by the addition of alloying elements, it is natural that iron founders should first have turned their attention to those elements which experience has shown to be eminently beneficial in the manufacture of alloy steel, since the chemical constituents of the two materials are essentially the same. That the effects of such additions would not be identical might, however, have been predicted from the wide dissimilarity between steel and cast iron in respect not only to the percentages of the several elements present, but also to the manner in which these are combined. A further difference is seen in that steel is more responsive to heat-treatment and the practical details of cast-iron founding, such as pouring temperature, cooling rate, and the dimensions and character of molds, are of much less interest to the steel maker.

As a matter of fact, the first step to be taken by an iron founder who wishes to improve the quality of his product is not to purchase expensive alloys, expecting these to overcome troubles caused by lack of attention to some fundamental principle of good foundry practice, but to check closely the quality of his raw materials, both as to physical properties and chemical composition; and to examine the operation and control of his cupola, with particular attention to the weights, arrangement, and size of the materials in each charge. When he is satisfied that these variables are correctly standardized further improvement may be gained by the judicious and practical use of alloying elements.

Combination of Nickel and Chromium Desirable

Of these elements chromium and nickel have received the most attention. Their beneficial effects on gray iron have been known since the earliest investigations, but it is only recently that enough data have been obtained to be of real help to the foundry-

*Metallurgical Engineer, Electro Metallurgical Sales Corp., 30 East 42nd St., New York City.

man. The physical properties imparted to cast iron by the addition of either chromium or nickel alone are of value in limited cases, but a combination of these elements in correct ratio affords a greater general improvement in physical properties than can be obtained by either one or by any other element alone. Nickel counteracts the hardening and chilling effect of chromium, while chromium counteracts the softening and graphitizing tendency of nickel. One thus supplements the other, producing a combined effect free from the disadvantages observed when either one is added alone in excess of certain well defined limits.

Earliest Investigation by Keep

The earliest work on the influence of chromium on cast iron is that of Keep, who experimented on gray cast iron with chromium additions up to 2 per cent. His results show a slight increase in strength up to 1 per cent, then a decrease. Campion later found that 1 per cent of chromium increased strength and hardness and also the proportion of combined carbon. Hurst states that in a cast iron containing 1 per cent of silicon, an addition of 0.9 per cent chromium produced a mottled fracture, while 4 per cent chromium added to an iron containing 1.5 per cent silicon rendered the fracture perfectly white; also that drastic annealing at 900 to 950 degrees Cent. (1652 to 1742 degrees Fahr.) failed to produce graphite. He also states that increasing the silicon tends rapidly to reduce the stability of the carbide. An iron containing 3.15 per cent silicon and 6.94 per cent chromium gave a Brinell hardness of 460 on a sand-cast bar, whereas a chill-cast bar was filed with difficulty. The same alloy containing 1.46 per cent silicon was glass-hard and white.

Summation of Some Investigations on Effect of Chromium

The systematic investigations of Smalley with chromium additions to ordinary gray iron and cylinder iron showed that in both cases small additions of chromium, 0.11 per cent and 0.15 per cent, increased the strength and hardness slightly; with a larger addition, 0.78 per cent, to the ordinary iron, the tensile strength fell, the transverse strength was little affected, and the Brinell hardness increased. A similar addition of chromium to

the cylinder iron produced an increase in transverse strength and Brinell hardness, but little change in the tensile strength. Piwowarsky's experiments show that with up to 0.50 per cent chromium, the strength and shock resisting properties of cast iron are increased by about 10 per cent, while the hardness increases from 20 to 25 per cent. Donaldson's investigations on a good cylinder iron with chromium additions of 0.19 per cent and 0.39 per cent show an increase of 5 per cent and 10 per cent in strength and 5 per cent and 11 per cent in Brinell hardness, respectively. Hamasumi showed that 0.40 per cent chromium strengthened an iron by 25 per cent without materially altering the structure.

Summing up the results of these investigators, it appears to be definitely established that 0.50 per cent chromium in the presence of 1 to 2 per cent silicon increases the tensile and transverse strengths and the hardness of gray iron. This increase in strength is due to the fact that chromium prevents the formation of graphite and produces a more stable double carbide of iron and chromium. (Strictly speaking, it crystallizes before the pearlite.) More recent work has generally verified the results of the earliest investigators, but it has also yielded data relating to improvements other than increased physical strength.

Effect of Chromium on Corrosion Resistance

Chromium has long been known as more effective than any other element in retarding certain types of corrosion reactions. Without chromium the stainless, rustless, and heat-resisting steels could never have been developed to their present high degree of usefulness. The need for a stainless or rustless cast iron has been so little felt that practically no work has been published in that direction. However, the demand for a heat-resisting iron to replace the more expensive high-chromium and chromium-nickel steels has led to the development of high-chromium cast irons for heat resisting purposes.

Irons containing as much as 18 per cent chromium have been made and tested for resistance to prolonged heating, under oxidizing conditions. Results from various tests have proved that chrome-irons containing 12.5 to 16.5 per cent chromium suffer

practically no loss when heated for 48 hours at 1000 degrees Cent. (1832 degrees Fahr.). The field for a cheaper heat resisting iron is almost unlimited, but unfortunately the high-chromium cast irons are hard and brittle and their commercial applications at present are, therefore, limited. However, it is not unreasonable to predict that high-chromium irons will be made for heat resistance work, with these objections considerably modified. Judging from the present work of investigators on the influence

FIG. 1—COARSE NEEDLE-LIKE CRYSTALS OF CHROMIUM CARBIDE STRUCTURE PRODUCED WHEN CARBON EXCEEDS 3 PER CENT

of different graphitizers, such as calcium-silicon, silicon-zirconium, and ferro-manganese-silicon, which when added to white iron yield some of the physical properties of gray and white iron simultaneously, it may confidently be expected that a similar treatment will be equally successful in reducing the brittleness of the irons highest in chromium.

The brittleness in high-chromium irons can be materially reduced, however, by maintaining the proper carbon content. If

carbon is too high, the alloy iron will be too brittle for many commercial applications, but if it is maintained under 3 per cent a much stronger iron is possible.

When carbon exceeds 3 per cent, coarse needle-like crystals of chromium carbide are formed, which reduce the shock resistance of the iron. When carbon is around 2.5 per cent a very dense, fibrous, strong iron is obtained. The photomicrographs in Figs. 1 and 2 show the unfavorable and the favorable condition. Fig. 1 shows the coarse needle-like carbides which produce weak-

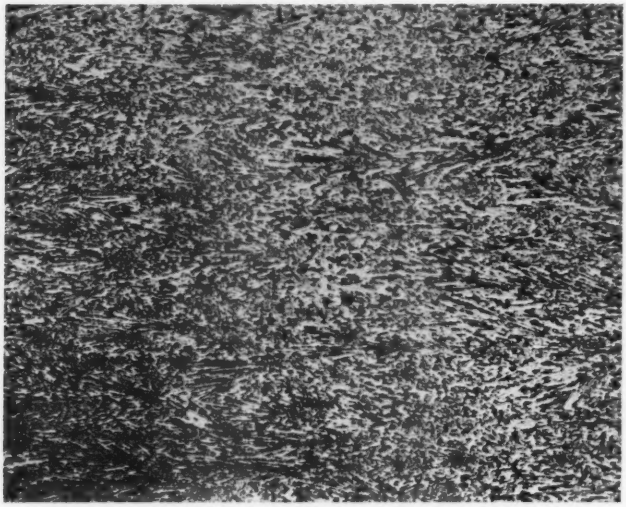

FIG. 2—SATISFACTORY STRUCTURE OF CHROMIUM IRON

ness. This iron contained 4.08 per cent carbon and 15.87 per cent chromium. Even with this excessively high carbon and hard, brittle structure, the transverse strength averaged 2566 pounds on the standard arbitration bars, with deflections of 0.044 of an inch. A more satisfactory structure is shown in Fig. 2, the iron having a higher transverse strength with a greater deflection. Iron containing carbon 3.26 per cent, chromium 15.16 per cent, and silicon 1.25 per cent gave a transverse strength of 4300 pounds and a deflection of 0.053 of an inch.

Low Carbon Cupola Iron a Problem

To obtain 2.5 per cent carbon in a cupola iron may present difficulties which will require some experimental work in the production of high-chromium irons by that method. Chromium increases the absorption of carbon by iron, but this can be offset by the use of sufficient steel or malleable scrap in the charge. Carbon absorption is negligible if the chromium content is under 1.5 per cent, but in making high-chromium irons extreme care is necessary to offset this absorption with its harmful effects.

Annealing to Reduce Initial Hardness

Annealing will reduce the initial hardness of high-chromium alloy irons, but has very little effect towards improving the transverse strength, which is comparable to that of ordinary cast iron, although the deflection is correspondingly low. This is illustrated by the data in Tables 1 and 2. For this test, bars containing as high as 14.68 per cent chromium were produced by the cupola method, which procedure will be explained later.

Table 1

CHEMICAL ANALYSES

Bar	C Per Cent	Cr Per Cent	Mn Per Cent	Si Per Cent	P Per Cent	S Per Cent
1	3.64	4.96	0.31	1.93	0.438	0.099
2	4.22	15.89	0.35	1.58	0.380	0.100
3	4.05	14.63	0.38	1.66	....	....
4	4.06	13.64	0.32	1.65	0.404	0.088
5	4.12	14.05	0.36	1.67	0.428	0.093
6	4.26	14.68	0.38	1.66	0.436	0.080

Table 2

PHYSICAL VALUES

Bar	Treatment	Transverse Load, 12-Inch Centers	Deflection in Inches	—Brinell Hardness— As Cast	Treated
1	Annealed	2700	0.040	512	477
2	Annealed	3850	0.054	512	444
3	Annealed	....	....	532	444
4	As cast	2425	0.040	512	...
5	As cast	2700	0.042	512	...
6	As cast	3175	0.048	532	...

The bars were annealed at 1000 degrees Cent. for 24 hours and tested, three bars "as cast" and three in the annealed condition. The effect of low silicon and high-chromium and their relation to the increase in hardness will be illustrated later.

Gray irons containing small percentages of chromium show pronounced resistance to oxidation at high temperatures, while plain cast irons, subjected to 1000 degrees Cent. (1832 degrees

Fahr.) for 48 hours, lose from 35 per cent to 60 per cent of their initial weight. Samples of alloy iron containing from 0.40 per cent to 18.50 per cent chromium, upon heating for 48 hours at 1000 degrees Cent. (1832 degrees Fahr.) showed a definite resistance to oxidation, the resistance increasing as the chromium content was raised to 13 per cent. With 2 to 7 per cent chromium, very little improvement is observed, while above 7 per cent the resistance increases with the chromium content, until at 13 per cent chromium oxidation practically ceases. This is shown in Table 3.

Table 3

Chromium Content, Per Cent	Per Cent Lost	Brinell Hardness
0.40	24.75	495
1.49	22.15	532
2.00	21.75	555
5.50	23.70	578
6.83	21.30	600
11.94	7.65	600
13.62	Slight gain	600
18.53	Slight gain	600

Bars for this test were ¾ inch square, cast in an iron chill. A standard arbitration bar 18 inches long by 1.25 inches diameter, and containing 11.94 per cent chromium, was cast in sand. This bar had a Brinell hardness of 387, and broke on 12 inch centers under a centrally applied load of 4125 pounds. Incidentally, samples having the same analysis were subjected to the salt spray test to determine their resistance to atmospheric oxidation. All of the samples rusted and with no apparent selectivity.

Oxidation tests on two electric-furnace products, instead of cupola iron, subjected to 1000 degrees Cent. (1832 degrees Fahr.) for 48 hours, gave practically the same results. The sample containing 7.30 per cent chromium lost 18.21 per cent and the one with 12.43 per cent chromium lost 2.60 per cent by weight.

Application of Heat Resistant Cast Iron

The heat resistance of chrome cast irons, even with small chromium contents, indicates their suitability for the manufacture of molds used in the casting of steel, iron, glass, and some of the non-ferrous alloys. The higher strength, hardness, uniformity, and grain refinement, due to the effect of chromium in putting

the graphite into a more resistive condition, adds considerably to the life of a mold, particularly of molds for the casting of steel ingots. In such molds, strength to withstand the alternate heating and cooling stresses, and a harder surface to prevent scorifying by the molten metal are two properties helping to prolong the life of a mold. Fire cracking on the surface of ingot molds is directly responsible for their short life in many cases. Furthermore, an ingot cast in a fire-cracked mold is badly defaced with ridges, which are sources of defects appearing later in the rolled billet. The demand for smooth surfaced ingots, especially in plants making steels of high quality, necessitates the scrapping of an ingot mold as soon as this defect appears, and correspondingly increases the mold cost per ton of ingots.

The heat-resisting chrome cast irons have an important application in the manufacture of annealing boxes, carbonizing pots, etc. Plain cast iron, subjected to prolonged heating, loses from 35 to 60 per cent in weight, while irons containing as little as 1.50 per cent chromium suffer only 22 per cent loss under the same conditions. Annealing pots containing 1.50 per cent chromium and sufficient silicon will show twice the resistance to heat of a plain iron pot at an increase in cost not exceeding $4.50 to $5 per gross ton of iron. Irons containing 2.5 per cent silicon and from 1 to 2.50 per cent chromium are not brittle, have fair machinability, and are resistant to abrasion as well as to heat, all of which properties are desirable in an iron used for this purpose.

Chromium and Strength Properties

A small addition of chromium increases the strength of cast iron, while further additions increase hardness at the expense of strength and deflection. The greatest strength is obtained when chromium is about 0.50 per cent with 1.50 to 2 per cent silicon, and is due to the fact that chromium prevents the formation of graphite. Reducing the silicon content increases the hardness like the effect of increasing the chromium content. Tables 4 and 5 illustrate the effect of varying the silicon content, while holding chromium at about 0.50 per cent.

Table 4

CHEMICAL COMPOSITION

Bar	C Per Cent	Cr Per Cent	Si Per Cent	Mn Per Cent	S Per Cent	P Per Cent	Brinell	Remarks
1	3.73	0.40	0.94	0.33	0.093	0.162	228	Mottled Iron
2	4.14	0.54	1.06	0.37	0.063	0.200	156	Gray iron
3	3.97	0.42	1.67	0.51	0.058	0.214	149	Gray iron
4	3.76	0.50	2.03	0.53	0.050	0.352	196	Gray iron
5	3.84	0.42	2.06	0.51	0.069	0.272	166	Gray iron
6	3.76	0.38	2.22	0.51	0.058	0.230	160	Gray iron

Table 5

PHYSICAL PROPERTIES

	Tensile Test		Transverse Test		Deflection
Bar	Cast, Pounds per Square Inch	Machined, Pounds per Square Inch	18-Inch Centers, Pounds	Calculated for 12-Inch Center, Pounds	in Inches, 18-Inch Centers
1	.....	21,940	1723	2928	0.200
2	18,150	18,463	1763	2981	0.170
3	18,925	23,776	1953	3305	0.220
4	34,275	33,400	2300	3883	0.198
5	.....	24,326	1952	3300	0.256
6	.....	23,850	2047	3462	0.270

Chromium and Silicon

The effect of increasing the chromium content, keeping the silicon constant, is shown in Tables 6 and 7. The range in chromium was 0.15 to 0.93 per cent with silicon around 2 per cent.

Table 6

CHEMICAL COMPOSITION

Bar	C Per Cent	Cr Per Cent	Si Per Cent	Mn Per Cent	S Per Cent	P Per Cent	Brinell	Remarks
1	3.79	0.15	2.12	0.61	0.054	0.470	187	Gray iron
2	3.68	0.19	2.08	0.54	0.058	0.424	207	Gray iron
3	3.89	0.31	2.05	0.55	0.048	0.216	163	Gray iron
4	3.84	0.42	2.06	0.51	0.069	0.272	166	Gray iron
5	3.92	0.50	2.05	0.47	0.057	0.218	159	Gray iron
6	3.69	0.69	2.02	0.50	0.048	0.364	183	Gray iron
7	3.84	0.81	2.34	0.56	0.057	0.266	187	Gray iron
8	3.85	0.93	2.35	0.47	0.044	0.219	179	Gray iron

Table 7

PHYSICAL PROPERTIES

	Tensile Test		Transverse Test		Deflection
Bar	Cast, Pounds per Square Inch	Machined, Pounds per Square Inch	18-Inch Centers, Pounds	Calculated for for 12-Inch Center, Pounds	in Inches, 18-Inch Centers
1	.....	28,056	2051	3460	0.190
2	29,700	33,153	2465	4170	0.243
3	.....	22,250	1755	2985	0.246
4	.....	22,443	1728	2919	0.260
5	.....	20,146	1592	2795	0.270
6	23,150	24,933	1635	2762	0.150
7	.....	24,326	1952	3300	0.256
8	.....	24,453	1858	3139	0.252

These data were obtained on test bars cast from 100-pound ladles of iron to which chromium additions were made in the ladle. A factor of 1.68 was used for calculating the values of

transverse tests on 12 inch centers, which factor was obtained by testing bars of the same composition upon both 18 inch and 12 inch centers. Tensile tests were machined from the broken transverse test bars.

Chromium and Carbon

It is generally understood that the higher the carbon content in gray iron, the lower the transverse strength. Tables 8 and 9 show the effect of increasing chromium in a high-carbon iron.

Table 8

CHEMICAL COMPOSITION

Bar	C Per Cent	Cr Per Cent	Si Per Cent	Mn Per Cent	S Per Cent	P Per Cent	Brinell	Remarks
1	4.10	0.04	1.00	0.41	0.066	0.206	134	Gray iron
2	4.08	0.05	1.34	0.39	0.079	0.202	137	Gray iron
3	4.01	0.08	1.77	0.48	0.075	0.208	140	Gray iron
4	3.97	0.24	1.66	0.51	0.056	0.198	144	Gray iron
5	3.97	0.42	1.67	0.51	0.058	0.214	149	Gray iron
6	3.98	0.48	2.29	0.48	0.062	0.288	212	Gray iron

Table 9

PHYSICAL VALUES

Bar	Tensile Test: Cast, Pounds per Square Inch	Tensile Test: Machined, Pounds per Square Inch	Transverse Test: 18-Inch Centers, Pounds	Transverse Test: Calculated for 12-Inch Center, Pounds	Deflection in Inches, 18-Inch Centers
1	17,900	16,540	1488	2516	0.183
2	21,850	16,277	1643	2779	0.215
3	23,255	17,300	1778	3001	0.213
4	17,337	20,366	1857	3139	0.210
5	18,925	23,776	1953	3305	0.223
6	27,650	34,720	2498	4220	0.225

It is evident that additions of chromium to cast iron improve its general characteristics. The transverse strength is increased and also the deflection corresponding to a given transverse strength. This is obviously due to the refining effect of chromium through its tendency to form a carbide at the expense of graphitic carbon. This is confirmed by metallographic examination.

Tensile strength is rather an unreliable property of cast iron. Additions of over 0.40 per cent chromium to gray iron show no improvement in the tensile strength.

Chromium and Machinability

The test bar containing 0.93 per cent chromium (Table 6) was machinable. Chromium up to 0.90 per cent and with sufficient silicon should have no adverse effect on the machinability of an iron. Primarily, the effect of chromium is to increase the rate of chill in proportion to the chromium content. Silicon has

the opposite influence on chill to that of chromium. When chill is desired, it can be obtained, either by increasing the manganese, using chills, or by lowering the silicon content, but an iron hardened by lowering the silicon is likely to yield inferior castings characterized by blow holes, high shrinkage, and poor machinability. By the use of chromium, hardness and fineness of grain

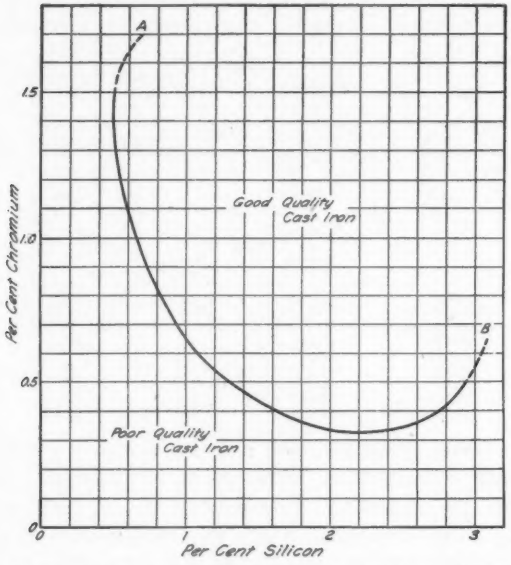

FIG. 3—QUALITY OF CAST IRON IN RELATION TO SILICON AND CHROMIUM CONTENT

can be imparted, the iron retaining some of the advantages of a higher-silicon iron.

Chromium Benefits Best Obtained by Silicon Adjustment

The greatest benefit from the use of chromium may be expected through adjustments between the chromium and silicon contents of a cast alloy iron. While many factors enter in, such as manganese and total carbon contents, temperature of pouring, rate of cooling, sulphur content, etc.,—the outstanding beneficial

element is silicon. Since silicon is a softener of cast iron, it is possible to offset its softening tendency and combine its other excellent characteristics with the hardening and strengthening properties of chromium. If we divide cast irons into groups having good and bad properties, based on transverse strength, machinability, soundness, density, etc., we shall find that, all other factors being the same, the properties are tied to the silicon and chromium contents by a general relationship shown on the accompanying curve[1] of Fig. 3.

The line A-B may be taken to represent the locus of a family of curves, each one representing some specific quality of the alloy and dividing the cast iron alloys of good quality from those of poor quality. An iron with low silicon content, say less than 1 per cent, and no chromium would have low transverse ductility and poor machinability. If the same iron contains chromium, however, it will be generally better. In case of a high-silicon iron the metal will be softened and made weak by the coarse graphite, but by the addition of chromium the metal is made tougher, the line A-B tilting sharply upward. While the shape of the curve is hypothetical, several series of investigations show its general form and position to be as indicated.

Hardness and Chromium

Hardness in iron can be obtained by sulphur, which likewise prevents the dissociation of carbon, leaving the iron hard but generally with low strength. Chromium imparts the same hardness, while at the same time increasing the strength up to a certain point, making a metal generally more desirable than one high in sulphur. This method of imparting hardness has been adopted by manufacturers of automobile cylinders, a type of casting in which wear resistance is of vital importance. Hardness can, of course, be obtained by the proper proportioning of carbon, manganese, sulphur, phosphorus and silicon, but such irons are likely to present machining difficulties later. Alternate heating and cooling of cylinders in service requires a structure which is not affected by this drastic treatment. A small percentage of chro-

[1] S. M. Norwood, Union Carbide & Carbon Research Laboratories, Long Island City, New York.

mium prevents softening of cylinder iron in service, while the possibility of soft cylinders, resulting from the annealing action of the cores during cooling of the casting, is greatly reduced. Tests on chromium-bearing cylinders showed only 8 per cent variation in Brinell hardness, while chrome-free cylinders showed a variation of 85 per cent.[2]

The ability of chromium to promote homogeneity by the proper distribution of the elements and preventing selective segregation during solidification makes it possible to produce castings uniform in structure and free from inherent weaknesses, which is the aim of all foundries dealing with high-quality products.

Application to Production of Grinding Balls

Due to the hardening properties of chromium, the application of chromium alloy irons for grinding balls, crusher plates and roll shells, ball-mill liners, and other parts subjected to abrasion, is receiving considerable attention. When silicon is kept low, chromium imparts extreme hardness, without the disadvantages of an iron whose hardness is obtained by a low silicon alone. As previously stated, equal or greater hardness can be obtained with chromium, the iron retaining some of the properties of a higher-silicon iron but with superior abrasion resistance. A grinding ball containing 0.70 per cent silicon, 0.70 per cent manganese and 3 per cent chromium has a Brinell hardness around 490, but by increasing the chromium, with the same or lower silicon, the hardness can be raised to around 600.

Balls having the following approximate composition, 0.40 to 0.50 per cent silicon, 0.50 to 0.60 per cent manganese, 3.50 per cent chromium, 2.90 per cent combined carbon, 0.40 per cent graphitic carbon, had a hardness of 530 to 560, and, contrary to the natural supposition, were comparatively tough. It is doubtful whether higher chromium would appreciably increase the hardness, unless used in combination with other elements or without resorting to a suitable heat treatment. There is also some question as to the possibility of having graphite in an iron of this

[2] E. J. Lowry, Metallurgist, Hickman-Williams & Company.

composition; probably all carbon existed in combination with the chromium as a carbide.

Where wear resistance is essential analyses similar to those given above can be modified to meet a multitude of applications. By lowering the chromium and raising the silicon, variations in hardness and strength can be obtained, keeping the total carbon and the phosphorus low at all times. Where strength and wear resistance are both required, increasing the section may be advisable to obtain sufficient strength while still maintaining the required hardness.

Resistance to Growth on Repeated Heatings

Considerable research has been expended towards attaining iron compositions which will resist growth to too prolonged heating or alternate heating and cooling. Charpy and other investigators definitely proved that gray iron, subjected to repeated heating, underwent a permanent increase in volume. The first assumption was that this change was due to the decomposition of cementite into iron and graphite, and that the decomposition could occur at temperatures below the lowest critical point. Later research has proved that this is not the case, as the decomposition of cementite does not account for the total increase in volume. Outerbridge later showed that a permanent change of volume was accompanied by a decrease in specific gravity, attributing this change to the expansion of occluded gases in the iron and assuming that these gases undergo an expansion at high temperatures, which in turn produces a permanent expansion of the minute cavities in which they are confined.

Rugan and Carpenter still later verified the findings of Outerbridge, and proved that this change of volume does not occur unless the iron is subjected to alternate heating and cooling, the change in volume depending upon the chemical composition of the iron. Increased silicon, which determines the graphite present, and graphite are the chief promoters of growth, which increases with the silicon content, the change in volume being caused by the oxidation of carbon, silicon, and iron.

Andrew and Hyman advanced the theory that elements aiding in the formation and expansion of graphite lamellæ, such as silicon and nickel, promote permanent change in the volume of an iron, and that chromium, although not entirely preventing this change, greatly aids in hindering this expansion.

Andre Levi[3] gives the following results as a sequel to the work of earlier investigators: Cast irons, subjected to repeated heating and cooling at temperatures not exceeding 900 degrees Cent. (1652 degrees Fahr.), undergo an increase in volume accompanied by a diminution of all mechanical characteristics. The increase in volume, following the first heat, is due to the decomposition of the cementite into iron and graphite. The subsequent increases in volume are due to the combined effects of internal oxidation and the formation of fissures, caused by the stresses produced in the metal. The extent of these volume changes is dependent on the size and form of the graphite lamellæ in the iron. Consequently, all elements which favor the formation or agglomeration of graphite lessen the resistance of the metal to high temperatures. The action of other elements which favor stable carbides is unfavorable to an increase of volume. In the manufacture of heat-resisting cast iron, it is desirable, in particular, to provide a high manganese or chromium content (about 0.40 per cent chromium), these elements forming stable carbides which resist annealing. Their stability retards increase in volume, subsequent to the initial heating, by reducing the amount of graphite, putting it in the form of round graphite nodules rather than acute-angled lamellæ. A judicious adjustment of silicon, manganese, chromium, and total carbon is necessary to secure the desired conditions in castings required to withstand the effect of high temperatures. The action of chromium in combining with carbon enables the iron to resist annealing and retards the separation of free graphite.

Effect of Nickel and Chromium

By the addition of both nickel and chromium, which two elements have opposite effects on graphitization, better physical

[3] Andre Levi, in a paper read before Glasgow Conference of the Institute of British Foundrymen.

properties can be imparted to a gray iron than are possible by an addition of either element alone. Nickel and chromium in proportions of three to one or two to one, depending on the silicon, afford an improvement in structure, strength, toughness, machinability, and resistance to abrasion.

Wickenden and Vanick,[4] after thorough investigation, state that additions of chromium in proper proportions with nickel result in increased transverse and tensile strengths. The highest transverse strength was attained with 0.76 per cent nickel and 0.32 per cent chromium, or an increase of 32 per cent over a base melt. Tensile strength, however, is favored by an increase in the ratio of nickel to chromium, the maximum being reached at approximately 1.20 per cent nickel and 0.40 per cent chromium in iron containing 2 per cent silicon. They recommend that irons with 1.50 per cent silicon should carry 0.75 to 1 per cent nickel and 0.25 per cent or less of chromium; for 2 per cent silicon irons, nickel 0.75 to 1 per cent and chromium 0.20 to 0.40 per cent; while for higher-silicon irons, say 2.60 per cent silicon, 0.75 to 1 per cent of nickel and 0.40 to 0.50 per cent of chromium are recommended.

Adding Chromium to Mixtures

The economical manufacture of alloy irons demands satisfactory methods for incorporating the addition of alloys, whether in a cupola or in the ladle. Chromium, available as ferrochrome, requires protection from oxidation by the blast when used as a cupola addition. The grade generally used is a standard product, containing 4 to 6 per cent carbon and 67 to 70 per cent chromium, although other grades, with carbon as low as 0.10 per cent and others with 6 to 8 per cent carbon, are available. Where a considerable tonnage of alloy castings is to be made, cupola additions are more satisfactory than ladle additions, which is also true when chromium in excess of 1 per cent is desired in the iron.

[4] Research Department, International Nickel Company.

Making Cupola Additions

Various methods are employed for making cupola additions, but it is never advisable to add ferrochrome loosely to the cupola charge; the resulting low and erratic recoveries of chromium are not only uneconomical but cause a lack of uniformity among castings poured from the same heat. Intimate combination of the chromium and iron is necessary to obtain uniform distribution, which is imperative for good machinability. The melting point of ferrochrome containing 6 per cent carbon is approximately 1250 degrees Cent. (2282 degrees Fahr.), a narrow margin below the temperatures obtained in general cupola practice.

Protecting the ferrochrome in metal containers improves the recovery over loosely charged alloy, but the highest recovery is attained by bonding or molding the crushed alloy into briquets, using cement or refractory clay as a binder. The ferrochrome, crushed to ¼ inch size, is thoroughly mixed in the proportions of one of cement to five parts of alloy. The binder should be of such consistency that each particle of alloy is covered, and there should be enough cement to permit the mixture to be formed into fist sized balls. By thorough mixing, each particle is completely covered, assuring cohesion of the particles, enabling the mixture to be formed into "balls," with sufficient strength for ordinary handling after drying.

After the balls are dried, they can be charged into the cupola in a manner to assure even distribution through the charge. Combinations such as chromium and nickel can be added by this means, although it is not necessary to protect nickel from oxidation; where the exact ratio of nickel to chromium is important, this method is particularly advantageous. The method is not limited to any particular percentages of chromium; experimental heats in which 15 per cent chromium has been introduced have resulted in 98 per cent recovery of the charged alloy and remarkable uniformity in character and analysis of the product.

Briquets and special alloys can be obtained from several sources, for making chromium and nickel additions to the cupola charge. The briquets are similar to the cement ball just described and any desired ratio of chromium to nickel can be obtained.

Ladle Additions

Ladle additions are sometimes necessary, as for an occasional casting, or at a foundry where both alloy and plain irons must be cast from the same cupola. Due to the chilling effect on the molten iron, ladle additions are limited to about 1 per cent chromium, although 3 per cent chromium has been successfully alloyed as a ladle addition. As the majority of all castings will run under 0.60 per cent chromium, ladle additions can be made to yield good recovery and uniform distribution of chromium if a suitable method is adopted.

Since iron temperatures at tap rarely exceed 1350 degrees Cent. (2462 degrees Fahr.) and the melting point of ferrochrome with 6.0 per cent carbon is around 1230 degrees Cent. (2246 degrees Fahr.), the necessity for hot iron and for conserving all available heat is apparent. Hot ladles, free from iron from previous taps, and hot iron from the cupola are necessary, especially if the ladles are of small capacity. An addition of 0.50 per cent chromium will go into uniform solution more readily in a 1000-pound ladle of iron than in one of only 100-pound capacity. Finely divided alloy is necessary and is available from 20 to 100 mesh, which is generally used.

The required amount of the pulverized alloy is wrapped in a paper sack, and this is thrown in, forcibly, as soon as the ladle bottom is well covered with iron. If it hits the place where the stream from the cupola drops into the ladle, the agitation there provides enough stirring to insure uniform solution of the alloy in the iron. Stirring may be necessary if the ladles are small or if there are any indications that the alloy is caking or floating.

Nickel additions can be made in the same manner. A special low-melting alloy, containing 92 per cent nickel, can be obtained for this purpose; it is known as F shot nickel, has a melting point around 1260 degrees Cent., and is giving excellent results. A nickel-chromium alloy in shot form can also be obtained, in ranges of 15 to 25 per cent chromium and 85 to 75 per cent nickel. These alloys have a sufficient low melting point to insure complete solution in the iron, and have proved economical and convenient for ladle additions. The variations in the nickel-chromium ratio

is another practical advantage. Good recovery of both elements, ease of handling, and uniformity of results, have demonstrated the practicability of this method for making simultaneous additions of the two elements to ladles of iron.

Ferrochrome as a Ladle Addition

There has been considerable difference of opinion as to the advisability of using ferrochrome for ladle additions. A test was run, using 20 mesh ferrochrome analyzing 4.8 per cent carbon and 67 per cent chromium, at a plant where chromium ladle additions were being made daily. The standard addition was about 4 pounds of ferrochrome to 1000-pound ladles, equivalent to 0.27 per cent chromium. Different methods were adopted for making the addition, some intentionally not ideal, to see the effect on recovery of chromium and uniformity of distribution. Analysis of tests taken from ladles receiving the addition under the most adverse conditions showed an average recovery of 90 per cent of the chromium added, while a variation between tests taken from the different ladles in this series did not exceed 0.03 per cent chromium.

A second series, using a different method of making the addition, gave an average recovery of 95.6 per cent of the chromium added, with a variation of 0.05 per cent between different ladles. A third series of samples were taken from ladles which had received the addition by the method previously described; recovery in this series was 98.5 per cent of the chromium added, with a variation of 0.01 per cent between ladles. Machining difficulties at this plant are almost unheard of, a further proof that the alloy goes thoroughly into solution and with uniform distribution.

Melting Point of Ferrochrome

Recent experiments performed in our company's research laboratory for the determination of the melting point of 70 per cent ferrochrome with different carbon contents, discloses a complex melting diagram resembling that of the iron carbon series. For practical purposes, the curve showing the initial melting of the alloy is satisfactory.

Starting with carbon free ferrochrome, the initial melting takes place at slightly above 1350 degrees Cent. (2430 degrees Fahr.). This gradually decreases as the carbon content increases, until at 4 per cent the curve strikes a point of about 1240 degrees Cent. (2232 degrees Fahr.). As the carbon content increases from 4 to 6 per cent, there is about a ten degree drop in the melting point.

Practical experience has proven that the best results are obtained with the carbon content between 4 per cent and 6 per cent. There appears to be no advantage in obtaining ferrochrome with carbon above 6 per cent.

Acknowledgment

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Discussion

G. S. Schaller: I should like to ask the author when on page 18? in the third paragraph, he makes the statement that in making cupola additions a recovery of 98 per cent has been attained, whether that is an average figure or is merely the best?

R. S. Poister: I will not say it is an average figure, because it hasn't been verified very many times, but the few times it has been done the recovery ran around 98 per cent of the alloy in the cupola charge.

H. S. Austin: The paper bears out my experience very closely. We find that about .4 per cent chromium is the best for high silicons, running down to .2 per cent for lower silicons. The effect of the silicon seems to have quite a little more influence on the chromium than the total carbons.

There is another peculiar thing about the addition of chromium. When your iron seems to be running a little hard, from a little oxidation or something like that, the chromium has a tendency to deoxidize the lower chills.

Our experience with a combination of nickel and chromium bears out the statement of the author that the iron is softened and the chills are lowered, making a more machinable casting.

L. L. Anthes: There is a point here I would like to have cleared up, something that possibly may create an argument. In the American Foundrymen's Association Bulletin of May on page 14 there is a reference to an

article on the creation of superior abrasion resistance by the introduction of chromium.

It says "A number of tests were made. First, cast iron in contact with rail steel; second, cast iron in contact with hard cast iron; third, cast iron in contact with soft cast iron. Contrary to what some writers have supposed, there is no connection between wear and Brinell hardness in cast iron, nor do present results show that chemical composition of material can give information as to possible wearing qualities. Quantity and orientation of graphite formed in iron has no bearing on resistance to wear. The main factor which governs wear is percentage of pearlite in the structure. Gray iron having a purely pearlitic structure exhibited the lowest degree of wear in the tests. The method of surface machining has great influence on wear."

On page 368 of Mr. Poister's paper he makes reference to the superior abrasion resistance by the introduction of chrome, and this quotation that I have just read seems to be more or less contradictory.

J. T. MacKenzie: I read that article in the Giesserie Zeitung, I believe. That was the finding. But the author also said that provided you had a pearlitic structure, the increase in Brinell hardness increased the resistance to sliding friction (the translation of that term), and that if you have a series of irons of equal Brinell, the one with the closest approach to the pearlitic structure would be the best iron. The abstract didn't bring that out.

J. W. Bolton: At one time or another all of us have wished that we had run more mixtures out of the cupola. Supposing you are running one, two, or three, and particularly in jobbing work, you might run against a casting for which none of your mixtures was adapted. I am making no brief for or against chromium, but I will say it has for some time been possible to help yourself out when you had too low silicon mixtures by the addition of ferro-silicon and perhaps better by the addition of nickel. In some cases where you have a chunk and you are making light work, it might prove very interesting to you to try some chromium in that iron, in that it has the same effect, in a very approximate way, as the reduction of silicon. I have tried that in a small way it has proved out very interesting.

E. J. Lowry: The author starts out with a real, honest statement, that is, that you must improve your iron after you have improved the base. Many foundrymen have tried to use chrome and tried to use nickel and they have been unsuccessful, whereas right next door you would find a foundryman making the same class of castings, using chrome or using nickel. It is always a question in my mind whether or not the man who fails to use an alloy to improve the quality of his iron hasn't failed to improve the quality of the base iron he is using.

Mr. Poister has given you some temperatures on page 373. He hasn't really given a fair chance to chrome. For instance, he tells you that iron at the tap rarely exceeds 1,350 degrees Cent., which is 2,462 degrees Fahr. A recent experiment down at the Lynchburg Foundry, made by the Bureau of Standards, showed that 2,372 degrees Fahr. was the ladle temperature, and

in many foundries where I have been working, taking tap temperatures, without corrections, we have gotten temperatures as high as 2,750 degrees Fahr. Therefore, as you consider the melting temperature of chrome to the temperature of your iron, you see you have a wide spread there to get good absorption. The difficulty in getting chrome to go into iron is because the foundryman doesn't pay attention, when he is adding to the ladle, to the size of the material he is using.

To come back to protecting ferro-chrome in metal containers, on page 372, and also using refractory clay binders, I know that there is somewhat of a doubt expressed about the 98 per cent, recovery, but in any number of tests which I have run I have found that I have gone as high as 100 per cent recovery when the material which is coating the alloy is at the proper melting temperature and has the proper fluxing degree to protect your alloy down through the melting zone.

On page 368 the author cites the ability of chromium to promote homogeneity. That is an absolute fact, and in one foundry that I know, melting quite a large tonnage, having but one mixture to play with, casting a heavy automobile cylinder as well as a light one, they found that the heavy cylinder was shrinking due to the fact that they were getting segregation. By the introduction of chrome—we started in at .10 per cent and went as high as .35—.35 to .38 was the point finally settled on to correct the trouble from shrinkage. Therefore, it has the ability to cut down your casting losses where you are manipulating your whole foundry product on one mixture.

The author states on page 366 that "chromium benefits are best obtained by silicon adjustment, which is absolutely true, but there is one thing that you must bear in mind, there is a limit to the amount of silicon used. In other words, if you were introducing ferrochrome to obtain .50 and you wanted to offset the hardness by the addition of silicon, if you get too high in silicon, then you begin to get a shrinkage. It is much better to go to the use of nickel, keeping your silicon as low as possible, so as to prevent shrinkage and get the machinability that you require by the use of nickel.

There is one point which foundrymen often debate. They say, "Why use a combination of chrome and nickel? If chrome gives you hardness and nickel gives you toughness, use both?" But they forget that when you put chrome and nickel into the iron, you get a structure which improves every physical property that you are looking for. The author should have laid a little bit more stress on that in order to show that there is a benefit by the combination.

MR. GREGORY: Some years ago we used to think vanadium was a cure all. I think it was because the government used to specify vanadium in their castings. We don't talk about vanadium so much in cast iron now, although there are traces of it. In the last few years we seem to have gone to chrome. I don't know exactly why, but it is possible that using chrome in steel, and steel being a pretty good material to work with, somebody had the idea we ought to put it in cast iron.

There is no question at all but that chrome has its place in cast iron, just like sugar has its place in coffee. It is a question of how much sugar you are going to put in your coffee. However, after we began putting in chrome, we used to think if a little bit was all right, a little bit more was better. That is where we used to make our mistakes. My experience, and I believe it has been verified by others, is that when you begin to go over .5, you begin to get into trouble. Now, I will qualify that by saying I am talking about the general automobile cylinder castings sections anywhere from three-eighths to a half inch. To my mind, chrome doesn't necessarily give you the perfect structure, but nickel has come along and when you get the proper combination of nickel and chrome, I believe we are getting to an ideal mixture, or an ideal specimen of iron for automobile work.

There have been various methods of adding chrome to the iron. We know that the melting point of chrome is not commonly the melting point of iron, and there are various ways of adding it. Some people like to put it in a briquette form in the cupola and let it come down, and that is fine if you are running a 100 per cent mixture of that type; but if you have a variation of castings; some thin and some light, some heavy, etc., then you perhaps have to make your ladle additions.

It has been my experience on ladle additions that you can get a 90 per cent plus recovery, I will venture to say a 95 per cent recovery.

One of the best ways I have found of adding chrome as well as nickel, is to have the nickel in shot form and the chrome, of possibly about an 8-mesh. I have found the best way to use nickel was by making a funnel that would set over the spout of the cupola, having a plunger that would drop down the hole of the funnel, put the required amount in, and at the proper time (we will say after you have run about 100 pounds in a 1,500 or 2,000 pound ladle), let the alloy drip through the funnel. Of course, the hole in the funnel has to be somewhat small, so the funnel will empty itself shortly before the ladle is full. I have found by that method you get a 90 per cent plus recovery every time.

D. H. Crosser: As to the method of using nickel or chrome or any other alloy, my experience has been that the cupola additions are much more effective than the ladle additions.

In almost every case that I have had anything to do with, I don't think it is any exaggeration to say we have recovered 100 per cent, although I never say that in talking about the recoveries that I might make.

Someone said something about abrasion resistance. All that I might say about that is that we have a company that is making grinding balls and they claim they have replaced the steel balls with cast iron. If that is so, it ought to be interesting to the cast iron industry. They have found that they outwear, that is, they grind more material than the steel balls. It is a question of getting the proper amount of nickel and the proper amount of chrome.

E. J. Lowry: Regarding this abrasion, I believe the paper that Mr. Anthes referred to was one on sliding abrasion, whereas the abrasion of

crusher balls is a grinding abrasion, or an impact abrasion, they are two different types; and as far as the paper that was read is concerned, I think the findings were without doubt true. I think when that author says that hardness has no relation to wear, I believe that is quite correct, and when he says that hardness has no relation to machinability, he is absolutely correct. Hardness, like analysis, is nothing but a guide. You aim at something. If you want to specify a Brinell, like 150, you just aim at it and you hope that with the proper constitution in your iron you are going to get uniform results. I have found that by the use of alloys such as chrome and nickel you come nearer to that than you do when you are just playing around with the ordinary type of iron.

MR. BOTHWELL: With reference to Mr. Lowry's statement and the question on the relation of hardness to wear, I think the German investigators speak of composite hardness, that is, taking into consideration the structural components, free cementite. It has been demonstrated, if you consider solid solution hardness, that there is no relation between wear and hardness, but there is considerably more wear in material containing free cementite than in an equally hard material with a solid solution hardness. That is, you can produce a material of a specified Brinell free of cementite, and you can also produce the same material with similar composite hardness, but this second material will wear at a greater rate than the homogeneous material of the same Brinell.

E. J. LOWRY: You say that the free cementite hardness wears away?

MR. BOTHWELL: It acts as a very effective abrasive, the small particles act as an abrasive between the two wearing surfaces. They drop out and they are flint hard, of course, and naturally accelerate the wear.

E. J. LOWRY: You are right so far as that statement goes, but, for instance, if you get into solutions such as a pearlitic structure, you will find that with the proper analysis in a pearlitic structure, your wear is less than in any other combination, at least those are the experiments that have been found and have been checked by one of the leading automobile industries.

MR. BOTHWELL: Speaking of a carbide free structure.

E. J. LOWRY: Yes. Now, in a case where you get a free ferrite, your wear, again, is induced.

MR. BOTHWELL: The point that I want to bring out is that two materials of the same composite hardness do not indicate their wearing service; micrographic examination is the only way to determine that. The material containing the most carbide would be the material that would wear at the greatest rate.

D. M. HOUSTON: Supplementing the statement here, I would say that Vanick has found since his original investigation in 1925 that pearlite formed from the carbides of iron and chromium broken down by nickel have been found to have the same resistance to heat before they break up into this formation, from chromium carbides. That these temperatures are just slightly below 1,700 degrees Fahr. is of very great importance in con-

nection with the difficulties that foundrymen are encountering in casting high chromium alloy castings. Very difficult castings are not practical, as indicated by the author, on account of the losses which such casting practices involve on account of cracking and that sort of thing. Now, by the addition of certain percentage of nickel as may be determined upon to this amount of chromium the nickel toughtens the matrix of the metal and very greatly overcomes these difficulties, often with comparatively small amounts of nickel. They can be entirely overcome by using a proper amount.

In addition, I might say this material has the distinct advantage of being equally as resistant to high temperatures as chromium in the carbide form.

I might mention this particular characteristic in just one other connection, and this was brought out, I think, by Mr. Bolton to some extent, and that is in castings of heavy section or in castings that undergo slow rates of cooling. During this slow period of cooling the plain iron-carbon compositions break down into their component parts at relatively low temperatures, let us say at perhaps 1,100 degrees Fahr. Now, taking advantage of the formation of these stable pearlite and sorbite formations at those temperatures (about 1,700 degrees Fahr.), it is possible to secure a more uniform structure in the heavy sections and thereby overcome the graphitization that is always a factor in slow cooling. This, of course, can be made use of commercially in any foundry where castings of heavy section are being produced.

Perhaps the only original thing I have to offer is a study made by Wickenden and Vanick in connection with the introduction of chromium alone in high silicon iron. The author on page 366 has a section of his paper entitled, "Chromium Benefits Best Obtained by Silicon Adjustments." Now, to a certain extent this adjustment should be made by silicon, but the question I have to ask the author is, why not make a nickel adjustment in the base composition? Because in one particular case I have in mind of approximately 2.65 silicon iron to which approximately .4 per cent of chromium had been added, this material was very close grained but there were some very unfavorable characteristics developed in the machine shop and under the microscope.

Now, under the microscope, the first of these was the formation of very minute holes. On the sample that was prepared and not etched for graphite distribution, these holes were not manifest. However, when it was etched with a 5 per cent solution of picric acid, instead of appearing to be graphite, upon examination they were found to be very small holes, definitely associated with gas pockets.

This led to further investigation of this phenomenon in high silicon, chromium iron, and it was found that this is very definitely a characteristic of those compositions.

In order to make sure that the hypothesis was right, the addition of a small amount of nickel was made in conjunction with the chromium, and these gas pockets immediately disappeared and they could not be made to reappear.

The second feature that Mr. Wickenden brought out was the fact that the difficulty encountered in certain parts of the test was due to knots of carbide, ferrite, pearlite and graphite, all four of those important constituents were very prominent in these knots. Now, these knots began to appear in base compositions of high silicon content to which .15 of 1 per cent of chrome was introduced, and, of course, increased in size and number as the chromium content was increased. These knots also gave way and were broken down by the introduction of a sufficient amount of nickel to destroy the carbide formations. Then, instead of having graphite and ferrite and carbide, you had only graphite and pearlite, and the difficulty of machining disappeared.

One other notable fact developed. The actual Brinell hardness was increased as this pearlitic structure was developed, bearing out the thing that Mr. Lowry mentioned just a few moments ago.

I want to supplement what was said in connection with the hardness values, the question that came up here just a few moments ago on abrasion and hardness. Now, if I understand the author correctly, in dealing with these hardness values he is dealing with a white iron. I understand the paper referred to had to do with gray iron and not white iron, and, of course, you are dealing then with two entirely different subjects, just as Mr Bothwell explained a few moments ago, and have really nothing to do with the subject in question.

Perhaps it may be interesting also to quote Mr. Vanick's developments along the line of hardness values in chromium and nickel-chromium mixtures. Hardness values of more than 600 Brinell cannot be obtained by the use of chromium alone unless the percentage of chromium is increased too. I am not quite sure of this figure but I think it is some place between 11 and 13 per cent. Is that right, Mr. Poister?

R. S. POISTER: I couldn't say. I believe around 7 or 8 per cent.

D. M. HOUSTON: However, a combination of nickel and chromium in the amount of about 1.5 per cent of chromium and 4.5 per cent of nickel created a hardness value when cast on a chill of 100 Rockwell-C, which is equivalent to 700 Brinell. On page 371 in the second line we have this sentence:

"Nickel and chromium in proportion of three to one or two to one, depending on the silicon, afford an improvement in structure, strength, toughness, machinability, and resistance to abrasion."

With your permission, I would like to add to that, "plus carbon," because your relationships are changed as the carbon is raised or lowered in connection with alloy applications, just the same as Mr. Bolton brought out in gray iron applications.

I heartily agree with everything that has been said about cupola additions and the manner in which they are made. I have one more method to add to the list which in my own experience has given as satisfactory results as any of the others I have used. Ferrochromium has relatively a low melting point, but its solubility point is low, particularly in ferrous

solutions. Now, what I mean by that is this, that if you had a composition of iron which melted at temperature given here, 2,282 degrees Fahr. and put that iron into a ladle of iron, it would go into solution almost immediately, in fact, it wouldn't be solubility, it would be actually melting. However, on account of the nature of the thing, chromium is very resistant, not only to solubility but to melting. In other words, there is a distinct difference between the melting point of chromium and the point at which it goes into solution, there is a resistance there. It is a characteristic. So that you have two actions in using chromium, one in the cupola, and one in making ladle additions. It is necessary to produce a product in making cupola additions which will entirely melt while the material is still in the melting zone.

Now, for cupola additions I have had very satisfactory results by taking a 4 to 6 per cent carbon—67 to 70 per cent ferrochromium and putting them in a paper bag or wrapping them up in a paper and throwing them down in the center of the charge, in the center of the furnace. The reason why we do that is to hold it together at least until the charge is effectively placed in the cupola. The recoveries of chromium, based on a 67 per cent alloy, in my own experience have been between 94 and 95 per cent. That is taken as an average covering perhaps, very nearly a thousand heats.

In connection with the ladle additions, I would like to just add this one thing to what Mr. Gregory has said. I agree with him on the manner of making this addition, I think it is at least covering my own experience the nearest to being fool-proof of anything I know. However, the careful selection of size of ferrochromium seems to be very important. It is important that ferrochromium, on account of the characteristic I have mentioned just a moment ago, its resistance not only to solution but to melting, makes it important that this product be ground fine enough; but when anything over 40-mesh is used, it is very much like dust, and by no method whatever have I been able to introduce ferrochromium successfully as a ladle addition in this dust form.

R. S. POISTER: Mr. Houston made a statement that he found it possible to add finely divided chromium as a ladle addition. I think he meant by the term "finely divided" something around 80 or 100 mesh. Is that not correct?

D. M. HOUSTON: Above 40 mesh.

R. S. POISTER: What size have you found in your experience is the best size for ladle additions?

D. M. HOUSTON: Ten to 12 mesh.

E. J. LOWRY: Commenting on what Mr. Houston said about the solubility of chrome and the melting temperature, it is obvious that the melting temperature is one governor and the solubility is the other, but that relation of solubility is governed by the temperature of the material into which you are introducing the alloy. In other words, if you attempt to get a good recovery by introducing ferrochrome into an iron at cold tem-

perature, you can't get the solubility, but if you are melting hot, you will find that the solubility has a direct relation to the temperature, just the same as the solubility of carbon and iron has a direct relation to the temperature.

D. M. HOUSTON: That was taken for granted. You must have hot iron when you are introducing alloys as a ladle addition.

MR. GREGORY: This chrome question is a deep question. I think those who have had a little experience with it ought to come out with it so the rest of us will get the benefit of it. I know the first time I tried it I was surprised to find that my chrome was almost in its original state right in the casting. I will have to say it was by a ladle addition, however. I think if there was some way of getting the chrome and nickel in the proper proportions in the pig iron, that would be the ideal way of doing it, and while there are pig irons that have it in, they don't always meet the shop specifications. I would just like to give people warning that in playing with chrome they should be careful with it at the start, but after you once find out what it is going to do or what it is doing, my experience is that it has brought out the carbides very strongly in the iron, but those carbides can be taken care of by the addition of nickel. And I have used nickel up to three and one-half per cent, whereas with chrome I very seldom dare to go above .5.

CHAIRMAN R. F. HARRINGTON: I would like to put forward the question of some means of obtaining the temperature of metals in which alloys similar to nickel and chrome are added. You know that today we are attempting to put on record the temperature at which our large castings, for example, are poured, not because we doubt the foundryman's ability to judge the temperature, but because we want to have it as a matter of record, and the moment we put any nickel and chrome or any alloy into the metal, we are out of luck so far as our ability to read that temperature by means of the optical pyrometer is concerned. I don't think there is any doubt as to our inability to get those readings.

J. T. MACKENZIE: Do I understand that that is a different color change in the stream?

CHAIRMAN R. F. HARRINGTON: We don't seem to be able to get the optical pyrometer readings at all correctly, it doesn't seem to tie up with the actual condition of the metal.

J. T. MACKENZIE: You don't get a fadeout with the filament?

CHAIRMAN R. F. HARRINGTON: No, you get the reading but the reading doesn't tie up with the actual physical characteristics of the iron as it does when the iron doesn't have the alloy in it. I said that I believed it was the experience of many persons that when nickel and chrome or nickel and chrome in combination were added to the ladle, the temperature readings as obtained by the optical pyrometer no longer became as reliable as they were when the nickel and chrome were not in the ladle.

I mean direct ladle additions. In other words, iron with the presence of nickel or chrome or ferrosilicon or any of those seemed to be out of line

with the optical pyrometer readings. I would like to know if we are "all wet" on it, as the boys say.

J. T. MacKenzie: At how low a percentage does that difficulty show up?

Chairman R. F. Harrington: At one and one-half of a per cent of nickel and a half per cent of chrome.

J. T. MacKenzie: The Gray Iron Committee just finished a series of tests on different carbon-silicon irons, but we never suspected that that point was of any importance, and I am sure we could extend that series of tests if it is of sufficient interest, so as to establish the true temperature of that metal and give you the comparisons with the optical. All you would have to do would be to establish the corrections.

D. M. Houston: The point that Mr. Harrington has raised very often comes up in field work. In fact, in several cases it has been necessary to convince certain people who are skeptical about the advisability of ladle additions, and which are really necessary commercially at this stage of alloy irons. The method of conviction was simply this:

To take a ladle of iron out of the cupola from a plain iron, together with the reading of the optical pyrometer, and put it in a 150-pound ladle, set it on the floor, a stop watch being put on the ladle as soon as the 150-pound ladle was pulled and a man placed there with a skimmer; and the next ladle that was coming out would be perhaps treated. In one particular case I remember we had an 800-pound ladle and there were 11 pounds of total alloy, and the difference in time, both ladles being treated in the same manner, was something like two or three seconds to the time when the iron actually formed a scum over the top of the ladle.

Now, to the optical pyrometer there was a difference of perhaps 200 degrees by reading it, and still, at the same time, when the iron was taken out on the floor, there was absolutely no difference that could be discerned between the alloy treated iron and the plain iron. In other words, there seemed to be a fluidity there that wasn't manifested in pyrometer reading temperatures.

Now, I will say this to Mr. MacKenzie. I can't speak for any other than just myself, but I certainly would be very much interested in the report of any investigation that your committee might conduct along those lines, and, if possible, to furnish an explanation of this particular phenomenon.

A. S. Wright: It is my experience that it is a difference in the color of the metal. I also might add that it is not confined to these nickel and chromium additions, but we have had occasion to make ferrosilicon additions and we find the same thing occurs; the metal has a different break entirely, and it also is in the color of the metal.

Chairman R. F. Harrington: Isn't it a fact that the temperature of the metal to which the nickel and chrome is added is apparently higher than the optical pyrometer would lead you to believe?

A. S. Wright: Yes. We tap the metal out around 2,700 and handle it for about five minutes and pour the casting, or take it in and get one of

the fellows to read it, and he reads it 2,530 or 2,525, when we know the stuff must be about 2,625. Mr. Houston made the remark that he thought there was about 200 degrees difference in temperature there. It has been our experience that it is nearer 100 or 150.

MR. BOTHWELL: I would like to state that in our laboratory and foundry we have successfully used Leeds & Northrup pyrometers and did not observe the difference in surface color, and we didn't observe the difference in temperature after the film had formed. There may be a more rapid formation of film or a difference in the time on the alloy iron to what there is on the plain iron. If you will observe a plain iron after it comes into the ladle and watch it through until the film forms, you will actually get an increase in temperature with that film formation.

CHAIRMAN R. F. HARRINGTON: We are trying to determine whether or not that pyrometer is the correct reading or whether we should have a great deal of respect for the practical man's judgment of the temperature of that metal. I think it is a very worthy thing for the Committee on Cast Iron to consider.

MR. BOTHWELL: Until that film forms, I don't believe there is any appreciable error introduced by the alloy. In fact, I haven't observed any difference in the temperature with the introduction of the alloy.

F. W. BAUER: I had some time ago an opportunity to check up your observations about the difference in temperatures with an optical pyrometer in high chromium and high nickel alloys and we found that we could not place any dependence at all upon the optical pyrometer readings, that they differed according to the composition of the chromium and the nickel alloys, and I just wonder if anybody by any chance has used a radiation type of pyrometer or odometer, as they call it, I believe, on obtaining the temperature of metal, and see whether they check up closely when there is a large percentage of alloy material. The optical pyrometer I know depends upon the color of the radiation which you observe with the eye, and the radiation type of pyrometer doesn't depend upon the color, so I thought you might have more success with that.

J. T. MACKENZIE: We tried radiation on those tests and the total emissivity varies more rapidly than the spectral emissivity, so as between the oxide iron and the clean iron the difference is tremendous. Twelve hundred degrees radiation is supposed to give you a true temperature of 1,700 on cast iron where the optical pyrometer will only correct 100. I took readings on the iron issuing from the stream with the radiation and got 1,900, and down in the ladle it was 2,200 and out in the shop it was 2,450.

R. B. SCHAAL: I would like to make this observation in connection with your pyrometer. I have had no opportunity to observe that on gray iron, but in the melting of stainless steel in the electric furnace we find that there is a tremendous discrepancy there. I suppose that that is increased by the temperature, the higher the temperature in the electric furnace over what it is in a ladle of gray iron. There is more difference there than, well, the difference is enough to throw the reading out entirely on an electric furnace.

Some Graphite Formations in Gray Cast Iron

By J. W. Bolton,* Cincinnati, Ohio

I.—GENERAL CONSIDERATIONS

The wide variety of shapes and sizes of graphite flakes in gray irons was commented on by the earlier metallographists. Since then most metallurgists have felt that the various curvatures, bunchings, and other formations in which graphite occurs in cast iron, must have some logical interpretation and practical significance. Many conjectures have been advanced. Several characteristic formations have been generally recognized. Among these are:—

(1) The broad straight flake formation, with a background of very fine flakes (shown in Fig. 1). This was soon recognized as characteristic in hypereutectic irons.

(2) The rosette, or whorl formation (shown in Fig. 2).

(3) The dendritic striation (Fig. 3).

(4) The grouped formation, consisting of clear definite dendritic lakes, the peninsulas being filled with fine graphite flakes (Fig. 4).

(5) The characteristic rounded "temper carbon" groups (Fig. 5). Flake forms have been described in the literature as curved, straight, hooked, star, uniform, irregular, etc.

Technique Important

In a study of graphite formations it is essential to give close attention to the technique of sample preparation. Gray iron is one of the most non-uniform materials (in hardness) with which the metallographist has to deal. Not only are undesirable relief effects too easily obtained, but without careful manipulation the graphite flakes may be severely distorted or obscured. An absolutely scratch free surface is not a positive essential for clear

*Metallurgist, The Lunkenheimer Co.

exposition, but both "drag" and "tearing" must be assiduously avoided. Inasmuch as a flake as photographed (See Fig. 6) is not flat (in one plane) sharp focus is hard to get. Slight focus above or below the true plane may cause the flakes to appear broad and coarse, or thin and fine, according to the manipulation of the focal distance. When too broad the edges usually have a hazy appearance, whereas if narrowed down, the edges seem to roll into the flake. Fig. 7 illustrates a rather evident example of tearing out of flake bunches in the polishing operation. Such large black areas have been called temper carbon by some.

Macrostructure

The general flake formations or characteristic segregations of gray iron are easily observed by the naked eye. In dealing with a material so structurally heterogeneous, there are two alternatives in its photomicrography. At higher magnifications a very *large print* is needed to give a clear idea of the *general* structure. (To be sure higher magnification has its part in resolving the more minute components and enabling the unraveling of their import.) The easier alternative[1] is study of macrostructure, say in the range of 20 to 100 diameters, preferably about 50.

Three Dimensional Conception

A micrograph reveals one plane only, that is, two dimensions. Flake formations possess three dimensions. For example, graphite flakes (so called) are not always very thin flat plates. The word flake seems rather well established, but it seems improperly applied to the individual graphitic pencils. The usual flakes are more rounded, rather irregular polygonal pencils. It follows too that the flake formations or groupings must be thought of in their three dimensions. For example, the rosette formation is essentially spherical, whereas the dendritic striations are effectively cylindrical.

Forms of Carbon

Pure carbon occurs in nature in two forms, diamond and graphite. The diamond crystal lattice belongs to the cubic sys-

[1] Bolton, J. W., *Study Structure of Gray Iron.* The Foundry, Aug. 15, 1924, pp. 628-634.

tem. Elementary silicon has a similar lattice. The specific gravity of the diamond is about 3.5.

Graphitic carbon is assigned to the hexagonal system, although its exact space lattic has not been satisfactorily established (insofar as the writer is aware). Graphitic carbon, or graphite as we will call it, possesses many of the characteristics of a true metal. It exhibits decided metallic lustre—any pig iron showing kish will illustrate this. Electrical conductivity is high and decreases with increase in temperature. Passage of current produces no apparent structural change. It is relatively insoluble (as such) except in certain metals. The specific gravity is given as 2.25. Because of conditions of pressure and of admixture with ferrite, too much practical significance must not be attributed to this gravity value. That is, the graphite portions of gray iron need not necessarily have a gravity of 2.25.

Cementite is iron carbide, conclusively demonstrated to possess the molecular formula Fe_3C. Its space lattic is a rectangular paralleopided[2] 6.77A° x 5.11A° x 4.53A°.

The specific gravity of cementite is given as 7.59. It is very hard, the hardest component of the iron carbon series.

It is soluble in most strong mineral acids and in molten iron. In presence of silicon, the cementite of carbon rich irons tends to decompose readily into its constitutents. This reaction is most rapid just below the eutectic solidification. Retained graphite nuclei accelerate this reaction.

Cementitic forms may be classified according to origin, as follows:

(a) Primary cementite (also called massive).
(b) Eutectic cementite (in ledeburite).
(c) Proeutectic cementite (rejected by austenite).
(d) Pearlitic cementite.

Phosphorus Formations

As has been pointed out by MacKenzie and Bolton, the steadite formations in most commercial gray irons are practically carbon free. For example, it was shown that an iron wholly

[2] Westgren and Phragmen, Journal Iron and Steel Institute, and Weaver, Publication of Kaiser Wilhelm Institute.

graphite, ferrite and steadite, contains all its carbon in the graphitic form, etc.

In every study it is seen that the steadite has been the last phase to solidify. The relative positions of graphite and steadite are added indication that the bulk of graphitization takes place above 1800 degrees Fahr. (graphite usually being near the center of the steadite shell).

Silicon

A few years ago it was commonly held that the combined carbon of a pearlitic iron should be in the neighborhood of .75 per cent. Excepting the ferrite in the pencils of graphite and in the steadite, examination of hundreds of samples has convinced the writer that an apparently pearlitic matrix is obtained at .55 to .60 per cent combined carbon. Investigations[3] in the malleable field show that silicon lowers the eutectoid percentage of carbon quite markedly. (Incidentally, the effect of silicon on the *eutectic* must not be overlooked. This is markedly lowered by silicon.)

There seems no reason for doubting that this action also obtains in the so-called gray irons. There are some objections which at first glance seem justified. Of course, the reduction of the silicon free eutectoid point from .85 to .92 per cent carbon is due to the reduction in volume of the effectively pearlitic matrix due to the precipitation of steadite and graphite. Again highest strength irons are usually assumed pearlitic and many of these irons show combined carbons up around 1.0 per cent. Examination of such high strength metals usually shows presence of some residual free cementite. A small amount of cementite seems relatively less deleterious to strength than a corresponding amount of its decomposition products. Beside the above and other considerations, there exists the uncertainty of combined carbon analyses—both due to the inevitable chance of mechanical losses, and to the chance of oxidation of graphite by reagents used in effecting solution.

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[3] Schwartz, Payne, Gorton, Austen, Trans. A. I. M. M. E., Vol. 68, p. 916 (1923), and Hayes and Wakefield, Trans. A. S. S. T., Vol. X2 (1926).

Ferrite

Ferrite in gray irons rarely if ever is found at the grain boundaries of pearlite, as is characteristic of certain steels, but almost invariably is found along the graphite pencils. See Fig. 8. The ragged fringe formation of decomposing pearlite along ferritic areas is a characteristic phenomenon. The distribution of ferrite in gray iron is, to the author's mind, added evidence of the existence of a ferrite solid solution, boydenite, as postulated and demonstrated by Schwartz. For that matter kinetic considerations demand this, and also admit the theoretical necessity of continued graphitization at temperatures far lower than those at which any appreciable reaction can be measured.

II.—DISTRIBUTION OF GRAPHITE

Some time ago, the writer made the following statement:[4] "*. . the structural forms of agraphitic (in this case cementitic) carbon have a profound influence on the structural arrangement of primary graphite flakes. . . . We may define and identify primary graphite as that first formed graphite which bears a structural resemblance to certain forms of agraphitic carbon. Secondary graphite flakes are those formed by agglomeration, growth, or rearrangement of primary flakes.*" Further work has substantiated the above. A number of related phenomena, both of practical and theoretical interest, have been noted by the author. Other investigators, notably Prof. Piwowarsky, have published data, of great value in themselves, and also helping in clarifying and extending work in the particular line referred to by the writer. In this connection there have arisen certain differences in nomenclature which might lead to confusion. These are explained in a later paragraph.

In examining mottled irons, chilled exterior and gray core, a set of conditions like those illustrated in Figs. 9, 10, and 2, often prevails. From this it is evident that *first formation of graphite is adjacent to the cementitic forms.* This is in agreement with certain well known physiochemical laws. Going further we find that certain of the formations—listed under Figs. 1, 2, 3, 4 and 5, either *bear in their structural outline a*

[4] The Foundry, Aug. 15, 1923, p. 663.

direct resemblance to potentially preexistent cementitic forms or certain other graphitic formations, perhaps not following a structural outline closely, ***seem characteristic of certain cementitic phenomena.*** In no case does the writer infer that there exist true pseudomorphs—the impossibility of such formation being readily apparent. Furthermore, the conditions are found in castings, whose charactistics at room temperature tend to preserve evidence of the influences of dendritic formation acting during their solidification. Reversing the operation, that is annealing, should tend to destroy dendrite evidences and promote more uniform distribution of graphite; and, except at excessively high temperatures, repress more thoroughly any tendency toward idiomorphic crystallization.

With the above in mind, let us give further consideration to the various forms, as listed in the first paragraph of this paper.

(1) Broad straight flake formation, with a background of very fine flakes, as shown in Fig. 1. The particular sample illustrated is 5.2 per cent carbon and low in silicon. It was slowly cooled. It is very decidedly hypereutectic, and practically all graphite and ferrite. Comparing to white irons, large plates of cementite, with filling of cellular eutectic ledeburite are characteristics of chilled hypereutectic irons, reminescent of the above gray iron, a coarse structure with filling of finely divided matrix.

From examining a few samples of kish, it seems that the graphite thrown out in this form may be subject to transverse cleavage, as the flakes or scales examined were flat and between a circle and a square in outline. A number possessed 60° angles.

The term graphite eutectic has come recently into frequent use. The fine matrix, as spoken of above and also shown in some of the subsequent illustrations, is a primary decomposition product of the cementite cellular eutectic. It may be found in hypoeutectic, eutectic, and hypereutectic metals. It is evidently not a true eutectic. It might conveniently be termed a pseudo-eutectic.

(2) The rosette, or whorl formation, shown in Fig. 2, is often a secondary decomposition product directly derived from pseudo-eutectic graphite—although it apparently may form at

times without the intermediate pseudo-eutectic phenomenon. It is one of the most common formations in the ordinary run of commercial irons. Because of insufficient area for its complete picturing, it is overlooked in most micrographs. It is characteristic in irons showing a network (as opposed to dendritic) type of macrostructure. Considered in three dimensions it is essentially spherical. The strength of the metal then is dependent on the effective distances between peripheries of adjacent spheres. Once having jumped the gap between surfaces of the spheres, fracture penetrates readily and in almost any direction through the ball, to emerge ready to jump into the weakest part of the next sphere and so on. Thus in spite of the sometimes small size of the individual graphite pencils, such iron falls among the weaker types.

Transfer from a pseudo-eutectic to a whorl formation is shown in the illustrations Figs. 11, 12, 13 and 14.

(3) The dendritic striation is more commonly observed in irons of lower (effective) carbon. It is particularly prevalent near the periphery of bars and castings. The core of the striation is graphite free, whereas the exterior graphite is probably precipitated from the ledeburite which has been rejected during the formation of the primary crystal. This formation is essentially a metallic core of distinct continuity surrounded by a cylindrical graphite pencil rich cylinder. The writer has noted that in this type iron the ratio of tensile strength over transverse strength in bars often is higher than that prevailing in more nearly eutectic-ferrous metal. This would indicate that the continuity is most effective in resisting stresses at right angles to the dendrites. This formation has some evidences of being secondary, of having undergone particle growth.

(4) The formation shown in Fig. 4 is very closely related to that described in the paragraph above. It more commonly occurs in irons rather rapidly cooled and of higher silicon content. The formation is distinctly primary. The core is largely austenitic, low in total carbon at its center. The graphite appears pseudo-eutectic, imbedded in a ferritic matrix. This is shown in Figs. 15 and 16. The formations usually occur close to the

exterior of the casting, and we have what at first glance appears an anomaly in that the skin is somewhat lower in combined carbon than the center of the casting is. The relatively rapid cooling has resulted in quick rejection of the higher carbon matrix with little opportunity for formation of long dendrites, as shown in Fig. 3.

(5) In certain cases of annealing the agraphitic carbon may separate in the distinctive temper carbon form, as in Fig. 5, although it often occurs that the carbon precipitates in distinctive graphite pencils.

From study of the above and other evidence, it is apparent that the *general distribution of graphite depends on the position of the alloy in the iron carbon diagram, silicon present.* Since this is the case even in irons free from eutectic, proeutectic and massive cementites, and since the formations are so remarkably similar in outline to the at least potentially preexistent cementitic groupings, this may be considered *some evidence that the cementitic groupings were not only potentially preexistent, but actually so.*

Conditions, such as relatively rapid cooling, through the range following dendritic segregation, promote the formation of forms distinctly resembling the cementitic groupings. For these formations we have proposed the term *primary graphite.* Slow cooling following the dendritic period, promotes diffusion and particle growth. In such cases the close resemblance is lost, the outlines of the formations are obscured. For the latter we have proposed the term *secondary graphite.* Obviously, there is no clear line of demarcation between these two forms—one merges into the other. From the writer's observations, the *stronger irons,* especially in the higher carbons, possessed a large proportion of this *primary graphite.* It is interesting to note the slight differences in composition or thermal gradients (or both) which produce remarkable variations in graphitization. Such an occurrence is illustrated in Fig. 17. It is often observed in the fractures of test bars and of castings. In a round test bar, the isothermal lines are presumably circular and concentric as regards the longitudinal axis of the bar. The "breaks" may not be at all con-

centric and on the axis—there may be a fine grained patch almost surrounded by coarse shiny portions. Then again in "shiners" or "framed" fractures the demarcation between the coarse and fine is often quite sharp. This suggests a very delicate balancing, i.e. sharp critical gradients. Determination of the effects of temperature, silicon, and alloying elements like nickel on the occurrence and intensity of the gradients is a very live research problem for the gray iron industry.

Hidden Properties

For many years experienced foundrymen have held that certain brands of iron give increased strength to the metal cast therefrom. Such opinions cannot be lightly disregarded. Too, there exists much evidence that steel additions have some strengthening influence over and above the effects attributable to their change in the analysis. It also has been observed that irons of like analysis may vary in their susceptibility to annealing. Many theories have been advanced to explain these apparent anomalies. Among the more popular of these have been the "oxygen" theory and the "rare elements" theory. In discussion from the floor (recorded in the 1924 Transactions of the A. F. A., p. 507), the writer pointed out that many of the phenomena attributed to "inherited" properties in the metal are reproducible by manipulation of cooling rate. Study of effect of gases on cooling rate, the effects of temperature of melting in the manufacture of iron, and, also, in the process of remelting upon the solubility of graphite in cast iron are suggested in this paragraph.

In a series of notable researches at the Technical High School at Aachen, Germany, Prof. Piwowarsky has shown[5] definitely that within certain temperature ranges the graphite in the pig and scrap of the mixture may not be completely dissolved in the cupola process. This residual graphite (called primary graphite by Prof. Piwowarsky) acts as nuclei on solidification of the metal, hastening the precipitation of more and coarser graphite. At higher cupola temperatures the residual graphite is

[5] Piwowarsky, E., *Progress in the Production of High Test Cast Iron*, Trans. A. F. A., Vol. 34, pp. 914-980, 1926.

completely dissolved and some undercooling takes place before precipitation occurs. Graphitization, occurring in a narrowed range and with no preexistent germinative centers, gives rise to larger relative percentages of those forms alluded to by the writer as primary graphite, and by Prof. Piwowarsky as secondary graphite. The difference is merely one of terminology. The writer thinks that if we consider precipitation from a *completely molten* iron carbon alloy (or more accurately, perhaps, an iron carbon silicon alloy), we are thinking of the *liquid phase.* Then the first formed graphite (not the already formed graphite carried through from the solid phase) is most accurately termed *primary graphite,* the forms resulting from changes incidental to diffusion and particle growth *secondary graphite,* and the graphite not dissolved in the gray iron melting process *residual graphite.* Prof. Piwowarsky showed further that temperatures in excess of resolution are detrimental to strength.

The late George Elliott was perhaps the first to utilize the higher temperature duplex process to produce high grade gray iron. Obviously steel, containing no residual graphite, serves as a diluent if not an absorbent of the residual formation. Prof. Piwowarsky and others have made high test irons utilizing superheat in the cupola. So far the theory holds good in a practical way. When it comes to proof that (as the theory demands) chill cast iron is appreciably stronger than sand cast, the writer has seen no conclusive results in commercial practice.

On the other hand, the charcoal iron theory was shown untenable after close scrutiny of Jominy's results[6]. The oxygen theory is unlikely, because, according to the Bureau of Standards[7], there is very little oxygen in solid cast iron. The mysterious elements theory has received very little bolstering, although something may turn up. Closer study of the effects of carbon (and of silicon) on gray irons has already explained away the majority of *big* apparent discrepancies anyhow.

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[6] Jominy, W. E., *Characteristics That Chemical Analysis Fails to Disclose in Pig Irons and Castings,* Trans. A. F. A., 1925, Vol. 32, pt. I, pages 476-509.

[7] Eckman, J. R., and Jordan, L., *The Oxygen Content of Coke and Charcoal Cast Irons,* Trans. A. F. A., Vol. 33, pp. 431-441, 1926.

SUMMARY

(1) Many of the characteristic graphite groupings in gray cast iron are shown either to—

(a) Follow in outline the shapes of potentially or actually preexistent cementite.

(b) Or, through tracing back the formation, to be derived from such cementite, yet possessing outlines not directly suggestive of such cementite forms.

(2) The groupings depend largely upon the position of the alloy in the iron-carbon (or perhaps more accurately on the iron-carbon-silicon) diagram.

(3) Consideration of the graphite groupings as three dimensional segregations suggests why *distribution* of graphite must be taken into account as well as *amount* and *individual flake size*.

(4) There is available evidence, both microscopic and analytical, for questioning the accuracy of the use of the word flake as descriptive of the individual graphite particles. However, like semi-steel, the name possibly serves its purpose.

(5) Careful technique in preparation and photomicrography of gray irons is necessary if accurate conclusions are to be drawn from illustrations.

(6) Pearlitic irons may have less than the .80 to .90 per cent combined carbon usually assigned to them.

(7) Most of the differences in physical properties of iron heretofore attributed to mysterious inherent properties, have been explained by closer study of the iron-carbon-silicon grain size relationships. Further, study of behavior of graphite during melting, etc., explains some other things. While there is no bright broad beam illumining the whole field, it can be said that many of the previously unexplained discrepancies no longer appear so puzzling. (Although enough remain.)

(8) The following nomenclature is suggested for description of graphite formations:

FIG. 1—HYPEREUTECTIC IRON FORMATION—UNETCHED—ABOUT 50 DIAMETERS

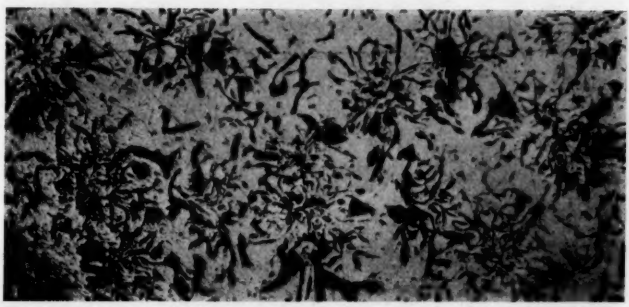


FIG. 2—ROSETTE OR WHORL FORMATION—UNETCHED—75 DIAMETERS

FIG. 3—DENDRITIC STRIATION—UNETCHED—75 DIAMETERS

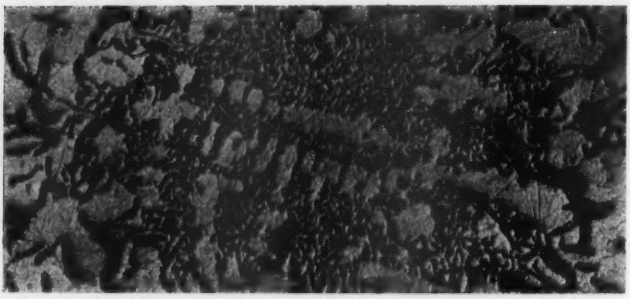


FIG. 4—DENDRITIC LAKES WITH PSEUDO EUTECTIC FILLING—UNETCHED—ABOUT 150 DIAMETERS

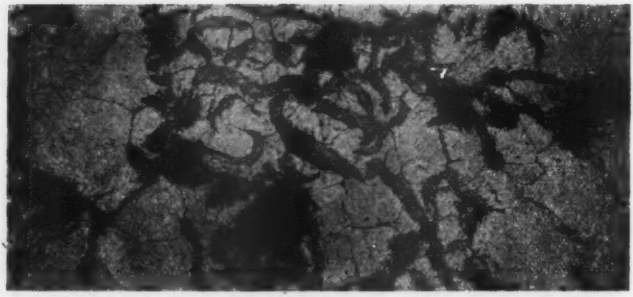


FIG. 5—TEMPER CARBON AND GRAPHITE—UNETCHED—300 DIAMETERS

FIG. 6—GRAPHITE FLAKES IN FERRITIC IRON, SHOWING DEPTH OF FLAKE—ETCHED—700 DIAMETERS

FIG. 7—TEARING OUT OF FLAKE BUNCHES, DUE TO FAULTY POLISHING —UNETCHED—ABOUT 100 DIAMETERS

FIG. 8—FERRITE ALONG GRAPHITE FLAKES—ETCHANT PICRIC ACID—100 DIAMETERS

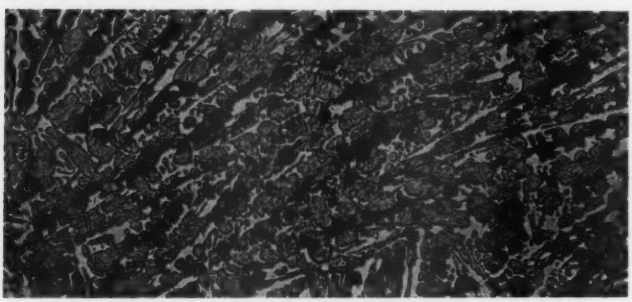


FIG. 9—MOTTLED IRON, GRAPHITIZATION JUST STARTING—75 DIAMETERS—SEMI-ETCH

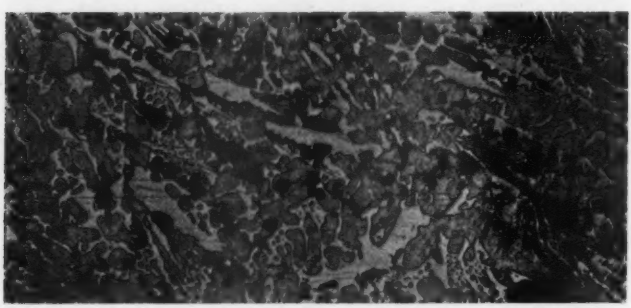


FIG. 10—MOTTLED IRON, PARTLY GRAPHITIZED—75 DIAMETERS—SEMI-ETCH

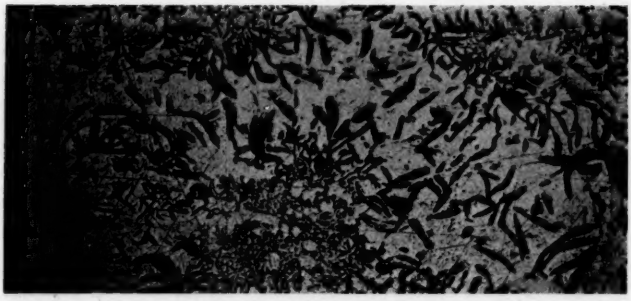


FIG. 11—LARGELY PSEUDO-EUTECTIC STRUCTURE NEAR EDGE—UNETCHED—ABOUT 100 DIAMETERS

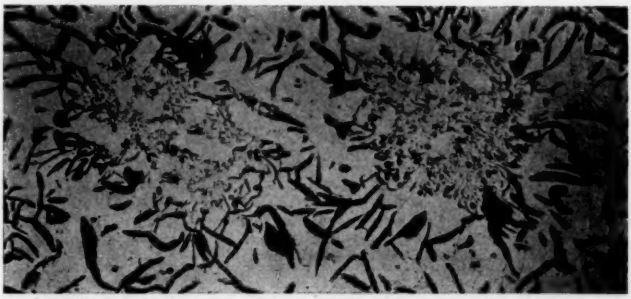


FIG.12—SAME IRON AS FIG. 11, NEARER CENTER OF SECTION—UNETCHED—ABOUT 100 DIAMETERS

FIG. 13—SAME IRON AS FIG. 11, STILL NEARER CENTER OF SECTION—UNETCHED—ABOUT 100 DIAMETERS

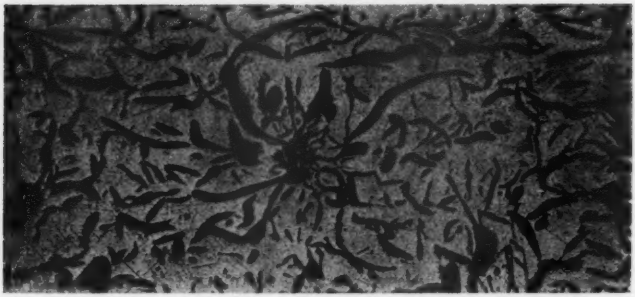


FIG. 14—SAME IRON AS FIG. 11, STRUCTURE AT CENTER OF SECTION—UNETCHED—ABOUT 100 DIAMETERS

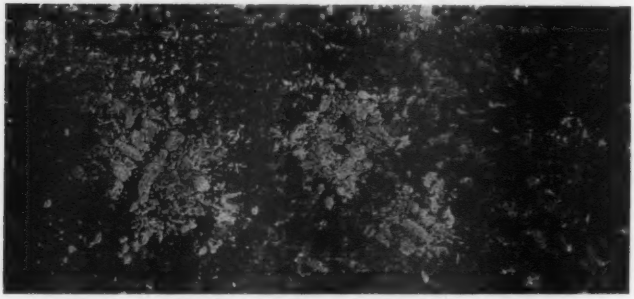


FIG. 15—FERRITE IN PSEUDO EUTECTIC GRAPHITE—ETCHANT PICRIC ACID—50 DIAMETERS

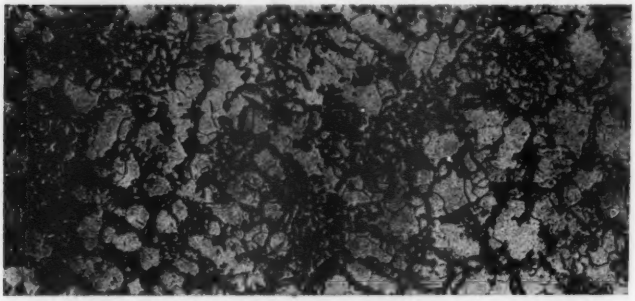


FIG. 16—FERRITE IN PSEUDO EUTECTIC GRAPHITE—250 DIAMETERS—ETCHANT PICRIC ACID

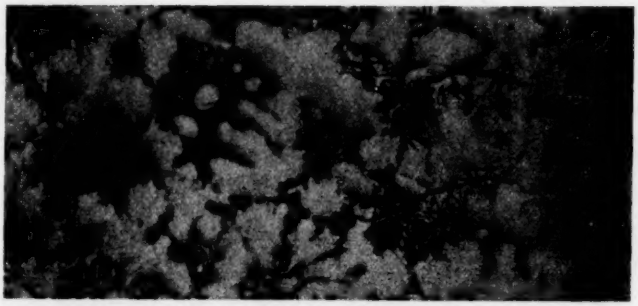


FIG. 17—UNDECOMPOSED PRIMARY GRAPHITE RESIDUUM IN GROUP OF HEAVY FLAKES—75 DIAMETERS—UNETCHED

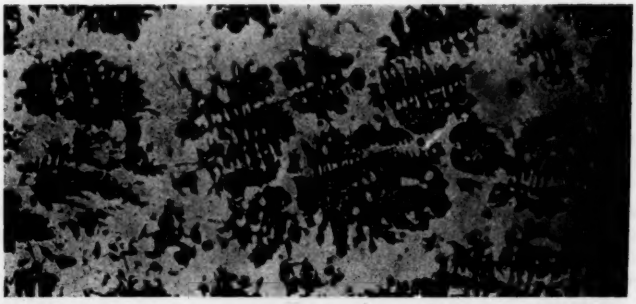


FIG. 18—FROM CASTING COOLED RAPIDLY FROM JUST UNDER SOLIDIFICATION POINT—UNETCHED—125 DIAMETERS

(a) *Primary graphite*—first deposited formations from liquid phase, retaining characteristic outlines resembling cementitic forms.

(b) *Secondary graphite*—formations, which, although distinctive, have, through influences of diffusion and grain growth, little resemblance to cementitic formations.

(c) *Residual graphite*—Graphite not dissolved in the remelting process, acting as nuclei on resolidification. Probably secondary graphite to start with and favorable to formation of more of this form on cooling again.

(d) *Pseudo-eutectic graphite*—Very finely distributed graphite, probably a decomposition product of ledeburite. This is one of the ***primary*** forms.

Discussion

J. T. MacKenzie: We all appreciate this summary of the graphite formations in gray iron, and I think if it hasn't done anything else, this paper serves a useful purpose in pointing out the technique of polishing, etc., on the appearance of graphite flakes. It also gives you the space conception of the graphite flake. When you see a photomicrograph and see a great, big, black splotch on it and then a long, black line, and then a point, it is hard to believe that all three of those pictures may have been made from three identical pieces of graphite, one of them lying in the plane of the specimen flat and the polishing operation drags the whole thing out; the next one running in the direction where you look down the line of it; and the third one you just clipped off the corner of it; so in this case you see a spot, in this case you see a line, and in this case you see what looks like the whole field.

I would criticize the author for not having given us any analyses on any of these photomicrographs he has shown. They are beautifully done and it seems that when they are published in the permanent record, if it is not too much trouble, we should have the analysis put under each photomicrograph.

I suppose it is outside the scope of the paper, but Mr. Bolton has listed five forms of graphite, the broad, straight flakes, the rosette, the dendrite, the grouped formation, and the characteristic rounded "temper carbon" groups, but he hasn't given us any inkling of how we would go about making one of these forms as opposed to the others, or are we forced to take a mixture of them, or how are we going to do it?

J. W. Bolton: I may say that Fig. 1 is what we know as a hypereutectice iron; it is not ordinarily obtained in commercial practice. As Mr.

MacKenzie happens to know, the iron is 5.2 per cent carbon, as he sent the sample to me about four years ago.

You will find the structure of that of Fig. 2 prevalent in irons that are more nearly what we call eutectic, where the sum of the carbon plus about .3 times the silicon totals 4.3. In other words, the iron runs around 3.4 to 3.7 per cent carbon.

The third is more characteristic of certain irons lower in total carbon, say in the neighborhood of 2.80, although you will find some of it in irons as high as 3.25 or 3.30 per cent carbon.

The fourth type is sometimes found on the outside of small castings of rather high silicon, 2.50 to 2.75, and carbon from 3.40 to 3.75. The white crisscross or pine tree structure is formed of crystals of prima austenite, which is the component that separates out first in the cooling of the cast iron and, separating out, it throws away from it, the carbon rich ledeburite. This graphite structure we call the pseudo-eutectic graphite.

In Fig. 5 the formation depends on the thermal treatment of the casting. If you go too high in temperature you get more chance of idiomorphic crystallization and these nodular carbon forms are more likely to change toward the characteristic graphitic forms.

This particular sample, shown in Fig. 6, is an iron of practically zero combined carbon, and the particular iron was about 3.40 to 3.50 carbon and in the neighborhood of 1.82 per cent silicon. However, the analytical percentages are immaterial from a structural point of view. The same structure might be shown in an iron of different analysis. Anneal it and you would get the same thing.

Fig. 7 is the picture referred to by Mr. MacKenzie. If you don't watch yourself in polishing you are likely to tear out a whole bunch of graphite and imagine you have temper carbon. This metal is about 2 per cent silicon and about 3.40 carbon and about .35 combined carbon.

These two samples of chilled irons are evidently fairly low in carbon; I don't remember the exact analysis.

Figs. 11, 12, 13, 14, 15 and 16 are the same iron and they are about 2 per cent of silicon and in the neighborhood of 3.20 carbon.

Mr. MacKenzie, do you mind explaining to the gentlemen how we came to get hold of this sample of 5.2 per cent carbon of Fig. 1? You are more familiar with the preparation of that than I.

J. T. MacKenzie: That sample is one of the buttons from the oxygen determination at the Bureau of Standards. That is a sample of the steel that was used in the sulphur and phosphorus investigation of the American Society for Testing Materials and the American Foundrymen's Association and that group. That sample has practically no silicon, I think .004. It was heated in vacuum for an hour at 1,450 degrees Centigrade in a graphite crucible and, of course, if you look up the iron-carbon diagram, you will find that that is just about saturated at 1,450 with 5.2 carbon. The influence of graphite nucleii on graphitization is shown very clearly, because you have no silicon whatsoever to assist in the graphitization of that iron and still

it is practically down to the pearlitic structure. There is only .80 per cent combined carbon in it out of 5.2 total, so you have 4.4 per cent graphite.

A little later than that I got Mr. Jordan to hold one for me at 1,130 degrees, which is the freezing point, for an hour, and we got that exactly 4.3 carbon, but the influence of the contact with the graphite crucible, and also, I presume, the fact that some of these flakes didn't quite get out, caused that sample even to be completely graphitized down to the pearlitic form; in other words, it still retained only .8 of a per cent of combined carbon, where any normal cast iron with that low silicon content, with no graphite to start reaction, would be absolutely white. In fact, I was wondering how I was going to touch the button and I found out it was so soft it was no trouble at all.

E. J. Lowry: I want to ask a rather impossible question of Mr. Bolton, but I think it is the one that worries the foundryman more than anything. It was a question asked by Mr. MacKenzie which Mr. Bolton very successfully dodged. He gave five different terms of carbon. We would like to know why those five different forms of carbon are present, also we would like to know which one of those five forms of carbon gives the best results in foundry properties and how do you get them.

J. W. Bolton: Of course, the first one is obviously an experimental iron. When you have this primary form, the very fine grain, is less effective in reducing strength. You may get more of it by superheating and having a shorter cooling range in between and you may get it in certain cooling conditions in the castings which cool just fast enough to preserve it and yet not quite fast enough to chill the iron. I may say that not only are the very coarse formations very weakening to the iron, but, a surprising thing, they don't always increase the machinability. You might think that the softer that iron was, the easier it would machine.

Hard iron may machine faster than soft iron under certain conditions. A coarse iron may clog up on the tool and be meaner to machine than a finer grained iron.

If you want to go ahead and get the big flake form shown first, you produce a very high carbon iron. If you want to get such a condition as in Fig. 2, which is a formation very commonly found in the lower strength cast irons, you get an iron somewhere near the eutectic percentage of carbon and cool it very slowly.

I think everybody who has worked with the lower carbon irons has found when dendritic formation is more prevalent, it is an indication of a lower carbon iron.

I may just say in passing that there is an observation I would like to check up before submitting to you as a fact. The lower carbon cast irons with that dendritic striation are stronger proportionally in tensile testing than in transverse, that is, the ratio of transverse to tensile is greater. It follows some work I published several years ago showing in large castings that lowering carbon was even more effective in keeping the strength up than lowering the silicon.

Now, this group formation, of course, is a eutectic formation, it is a primary product whereas No. 2 is a secondary.

The temper carbon, of course, is a malleable annealing proposition.

You want to remember one thing, relative to this whole proposition. You will find, for example, if you take any hypoeutectic iron, it will contain some eutectic structure and it will contain some austenitic structure. That is to be expected. You see that in this series of pictures in Figs. 11, 12, 13 and 14. You have a primary formation pretty apparent on the outside and when you get on the inside, your cooling rate has delayed the particle growth.

E. J. LOWRY: Is it my understanding that if any one of these carbon forms would be detrimental to your casting work you could escape that form by superheating your iron?

J. W. BOLTON: To a degree. You know, we have all been pretty much pleased the last few years to find that the old foundryman's way of saying "melt it as hot as you can," is usually pretty sound sense. You have in your pig iron graphite, and if you re-melt that in a cupola at a very low temperature, it doesn't entirely dissolve and the bigger flakes are thrown down on cooling and you get a coarser grain.

E. J. LOWRY: Does this residual graphite that you talk about occur in every pig iron.

J. W. BOLTON: No. I think the superheat business has its limitations just like any of these things; you have to take them all and apply them to your own work and be very careful in doing it. Theoretically, according to Piwowarsky, who has investigated that particular angle of it more deeply than the rest of us, if you get an absolutely chilled iron that has no graphite whatever, it will be stronger, and I think his experimental work pretty well bears that out.

E. J. LOWRY: If you chill your iron, you get less trace going through. Chilled pig iron has less power of carrying this germ or nucleii or residual carbon than would an ordinary sand cast iron.

J. W. BOLTON: As far as it goes, yes, but you can give us a sand cast iron and we can put it through the duplex process or even take the cupola and operate it hotter and you will find its strength curve by following the different sections' sizes is progressively put over to the right, according to the heat at which that iron is melted.

E. J. LOWRY: Then, consistent with that, superheat does destroy the germs of residual carbon if they follow through in any form of iron.

J. W. BOLTON: So Professor Piwowarsky said and so our own experiments demonstrate as true. However, the thing that we are trying to bring out in this paper is not particularly related to that particular phenomenon, it is a general thing and that is incidental.

R. B. SCHAAL: When we get into these metallographic questions, we are usually treading on pretty thin air. Of course, we all appreciate that Mr. Bolton's work here has been quite exhaustive, and it is very valuable, but

I would like to give you gentlemen a little data that applies only, of course, to our work, but it is along these lines.

There has been a general impression that iron which contains a large percentage of ferrite in the structure and also which is of the rosette or whorl formation, is weaker by nature than almost any other kind of iron. We find in our work that this is rather erroneous. We find that it is stronger than any other kind of iron for our own purpose, which is stove work, gas stoves, all thin section work, of course. We have found that a pearlitic structure will not give us anywhere near the transverse strength on the inch square bars that this same rosette formation will give us with a large percentage of free ferrite. We have been able to obtain bars which will give us a transverse strength, that is, the inch square bar, not the arbitration bar, of 3,200 pounds, whereas we have never yet found any of our iron which you might say was pearlitic or which is actually pearlitic, which would give us a strength of over 2,500 or 2,600 pounds.

Now, that is due, as Mr. Bolton has pointed out, more to the size and shape of the graphite itself than it is to the pearlitic structure or to the ferrite structure. We find that our pearlitic structure usually contains graphite in large particles. Therefore, it is quite misleading to say that a pearlitic structure is stronger than a ferritic structure.

We also have found in making these transverse tests and measuring the deflection that the ferritic bars are considerably more flexible and therefore, of course, much better adapted to light work. There is no particular trick about securing an iron of that character. Stove iron, of course, is generally accepted to be around 2.70 silicon, about .65 to .70 manganese, about the same amount of phosphorus and we have found that a sulphur of .11 or .12 doesn't seem to make any difference. Then our carbon, of course, with the 2.70 silicon, will run around 3.40. We are able to keep the combined carbon on those test bars down as low as between .10 and .20. The first iron from the cupola, of course, is not that low, that will run around .60, and that is all pearlitic structure and it is weaker. That is about what it runs.

J. T. MacKenzie: The Diefenthaler process of pearlitic iron is based on a heated mold and obtaining pearlitic iron with a low carbon. You mustn't forget in discussing pearlitic iron that if you get it by means of high carbon that is pulled in, say, a thin section, just to the .80 combined carbon, or .70 or .60 or whatever it may be, that you have in that case 2.75 graphite. Now Lorenz or Diefenthaler, whichever one of the Germans did invent the process, takes a low silicon iron with about 3 per cent carbon, even down to 2.75, and with a heated mold as you come in graphitizing the iron, leaving the .75 combined carbon. That leaves them only 2 per cent graphite.

Now, if we assume that the pearlite in one case is as strong as the pearlite in the other, the presence of three-quarters of a per cent more graphite would undoubtedly explain the difference in the character of the two irons.

R. B. SCHAAL: I think that Mr. MacKenzie is probably right to a great extent in those remarks, but in this way he is not. He has forgotten to take into account the size of these graphite particles, the size and shape of them. If the graphite is fine, of course, the pearlite will be as strong in the one case as the other, but the iron, regardless of how much graphite there is in it, within certain practical limits, if the graphite is fine, the specimen will be stronger than if it is coarse. We have found that to be the case in a great many tests.

When I was making my previous remarks, I was referring, of course, to a high silicon iron. I might have emphasized the point that where both the irons that I was speaking about, both the ferritic and the pearlitic irons ran 3.40 total carbon, it is easily seen that the ferritic iron contains more graphite than does the pearlitic iron, the difference being in its distribution and size and shape of the particles.

E. J. LOWRY: I think Mr. Schaal has forgotten that as you vary the silicon in an iron, in an iron-carbon iron, you vary the solubility of carbon in the pearlite, therefore, under all conditions pearlite doesn't have the same strength. For instance, with a low silicon, as has been shown by Payne and Harry Schwartz and a number of others, with a one per cent silicon you get a different carbon in your pearlite than you do when you are up to 2.70, such as the iron that Mr. Schaal is using.

J. W. BOLTON: Translated to approximate mechanical effects, all the remarks simply indicate two things: the lower your total carbon and the finer your grain size, the stronger your material will be, other conditions being equal.

Fatigue Tests of Cast Iron

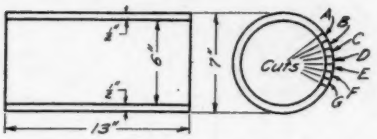
By H. F. Moore* and S. W. Lyon†

Cast iron is occasionally subjected to repeated stress in service. There are very few available test data on the strength of cast iron under repeated stress. As the result of a cooperative arrangement between the Allis-Chalmers Manufacturing Company and the University of Illinois a short investigation of the fatigue strength of several kinds of cast irons has recently been made. The results of this brief investigation, while by no means covering the field, do afford some test data in what is practically an unexplored field, and meager as these results are it is believed they will be of interest to foundry men. This investigation has been carried on as a part of the work of the engineering experiment station of the University of Illinois, under the administrative direction of Dean M. S. Ketchum, director of the station, and Professor M. L. Enger, head of the department of theoretical and applied mechanics. A somewhat more extended report of the investigation is now in press as bulletin 165 of the station.

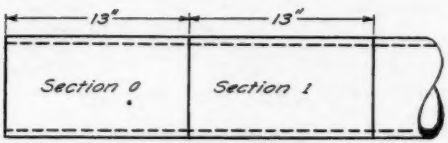
Scope of Tests

In any study of the strength of cast iron, or of any cast metal, two distinct problems are to be recognized: (1) the study of cast iron as a material, and (2) the study of the effective strength of the material in different parts of a casting. The second problem is modified by such factors as internal strains, minute cracks, varying rate of cooling of different parts of casting, inclusions of dirt and slag, and the form assumed by the flakes of graphite in the cast iron. Problem (1), the strength of cast iron as a material, may best be studied by means of tests of specimens cut from castings of simple shape, and cast under carefully controlled foundry conditions, since in such parts the cast iron is most uniform in quality and the effects of irregularities are least. It is evident that the study of the effective

*Research Professor of Engineering Materials, In charge, Investigation of Fatigue of Metals, University of Illinois.
†Engineer of Tests, Investigation of Fatigue of Metals, University of Illinois.



Cuts in a Section of Pipe



Pipe Cut in Sections

FIG. 1—DIAGRAM SHOWING METHOD OF CUTTING UP PIPE AND LOCATION OF SPECIMENS

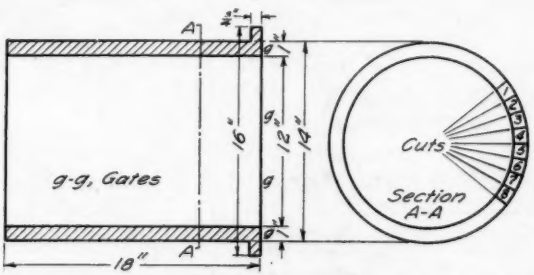


FIG. 2—DIAGRAM SHOWING METHOD OF CUTTING UP CYLINDER AND LOCATION OF SPECIMENS

strength of cast iron in different parts of complicated castings would be a much more difficult matter.

In this paper it is the first problem which is studied rather than the second.

Source of Material Tested

The four different lots of cast iron tested are hereafter referred to by the laboratory numbers 91, 92, 93 and 94, assigned for purpose of identification. Test specimens for cast iron 91 were cut from a section of 6-inch cast iron pipe purchased on

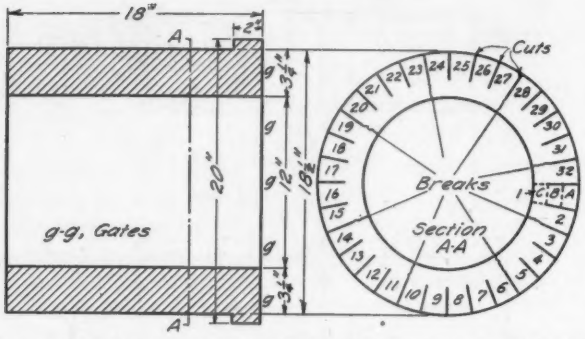


FIG. 3—DIAGRAM SHOWING METHOD OF CUTTING UP CYLINDER AND LOCATION OF SPECIMENS

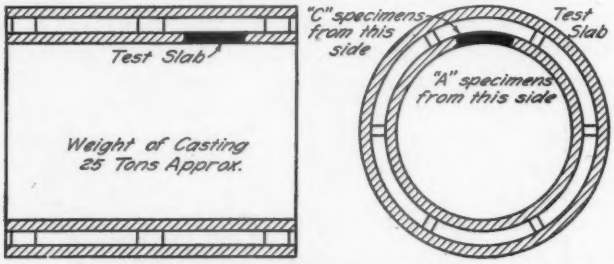


FIG. 4—DIAGRAM SHOWING GENERAL LOCATION OF SLAB FROM WHICH SPECIMENS WERE CUT

open market. The centrifugal casting process in horizontal refractory sand molds was used in the fabrication of this pipe. Fig. 1 shows the location of specimens in a section of pipe.

Cast irons 92 and 93 were obtained from hollow cylindrical castings supplied by the Allis-Chalmers Manufacturing Company. Both cylinders had narrow flanges at one end and were cast in green sand molds having dry sand cores. The approximate wall thicknesses of the cylinders for cast irons 91 and 92 were one and three inches, respectively. Figures 2 and 3 show in detail the size and shape of these castings.

The slab from which cast iron 94 was obtained was cut from the inner wall of a double-wall cylinder casting weighing

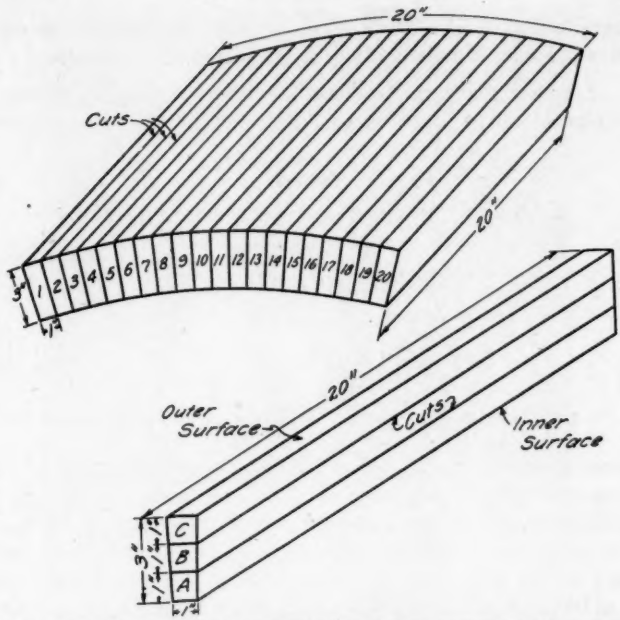


FIG. 5—DIAGRAM SHOWING GENERAL METHOD OF CUTTING OF SLAB AND LOCATION OF SPECIMENS, CAST IRON SLAB CUT FROM LARGE CASTING

approximately 25 tons. Fig. 4 shows the general location of the slab from which specimens were obtained and Fig. 5 shows the location of the specimens cut from this slab.

Chemical Composition and Metallographic Structure of Cast Irons Tested

The chemical compositions of cast irons 91, 92, 93 and 94 are given in Table 1. The analyses may be considered fairly representative of good gray cast iron. The existence of practically all of the carbon in cast iron 94 in the graphitic form is especially worthy of note.

Fairly extensive microscopical examination of unetched specimens of the various irons showed no appreciable segregation of graphite. The micrographs shown in Fig. 6 were taken at a

magnification of 75 diameters and are believed to show representative graphite distribution for the various cast irons tested.

Supplementary microscopical studies of etched specimens were made for the irons tested. The micrographs of Fig. 7 show

Table 1

CHEMICAL COMPOSITION OF CAST IRONS TESTED

Cast Iron Lab. No.	Content, per cent						
	Silicon	Sulphur	Phosphorus	Manganese	Graphite Carbon	Combined Carbon	Total Carbon
91	1.42	0.065	0.75	0.32	2.72	0.84	3.56
92	1.10	0.093	0.51	0.62	2.76	0.68	3.44
93A	1.10	0.095	0.51	0.63	2.80	0.55	3.35
93B	1.10	0.094	0.51	0.59	2.78	0.57	3.35
93C	1.10	0.096	0.46	0.60	2.82	0.43	3.25
94A	1.16	0.102	0.38	0.58	...*	...*	3.32
94B	1.14	0.100	0.38	0.61	...*	...*	3.30
94C	1.13	0.103	0.40	0.57	...*	...*	3.30

*Combined carbon was less than 0.05 per cent, nearly all carbon was graphitic.

representative areas and were taken at a magnification of 750 diameters. Fig. 7 indicates that for cast irons 91, 92 and 93 lamellar pearlite is the dominant crystalline constituent present. This dominance of pearlitic structure is to be expected with these irons as the amounts of combined carbon would indicate from 50 to 95 per cent pearlite (excluding effect of silicon, etc.). Occasional grains of steadite[1] are discernible surrounded by the lamellar pearlitic structure.

Cast iron 94 cooled much more slowly than the other irons tested due to the large mass of the casting, thus causing the carbon to be deposited almost entirely in the graphitic form, as indicated by the chemical analysis. As can be seen from Fig. 7, ferrite is the dominant crystalline constituent, with scattered areas of pearlite in evidence, usually around occasional grains of steadite. These scattered areas of pearlite in a ferrite matrix are to be expected as the chemical composition indicates some 5 per cent pearlite. This pearlite varies from the lamellar form to the globular, with the transition stages in evidence.

All the irons were tested as cast. No special heat treatment was applied either at the foundry or in the laboratory. Cast iron 91 was allowed to cool in the mold, not shaken out while still hot, as is quite common practice for centrifugal-cast pipe.

[1] Steadite is a phosphide eutectic.

FIG. 6.—MICROPHOTOGRAPHS OF SPECIMENS —X75, UNETCHED

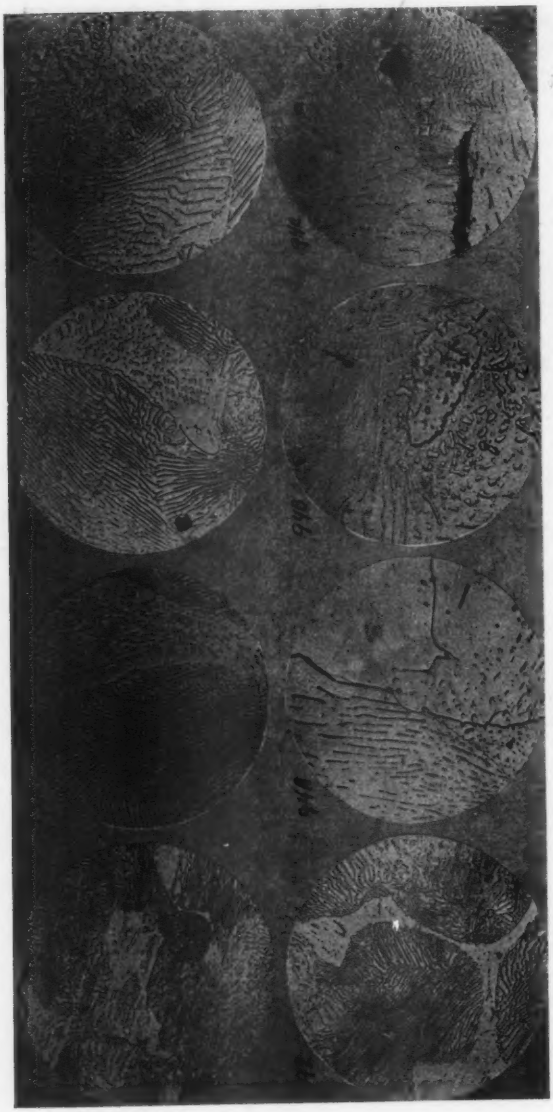


FIG. 7—MICROPHOTOGRAPHS OF SPECIMENS —X750, UNETCHED

Test Specimens and Methods of Testing

Test bars were cut from the pieces of iron furnished as shown in Figs. 1, 2, 3 and 5. These test bars were then cut up into specimens for static tension tests, for Charpy notched-bar tests, for repeated-impact tests and for rotating-beam fatigue tests. The form and size of the specimens used is shown in Fig. 8. It should be noted that since the thickness of wall of the pipe from which the specimens of cast iron 91 were cut was only ½ inch it was necessary to make the tension specimen and the rotating-beam specimen for cast iron 91 slightly smaller than those shown in Fig. 8. The tension specimens of cast iron 91 were made 0.3 inch minimum diameter, and the rotating-beam specimens were made 0.325 inch minimum diameter and 0.400 inch maximum diameter.

The tension tests were made on a 100,000 pound three-screw Olsen testing machine. The tension specimens were specially designed to avoid stress-concentration near the critical section. They were held in Robertson shackles,[2] shown in Fig. 9, which are designed to minimize flexural action on the specimen. In the case of cast iron, 91 tests, with specimens as shown in Fig. 8 (b), held in Robertson shackles, raised the value obtained for ultimate tensile strength about 12 per cent above that obtained for specimens having parallel sides and held in ordinary spherical-seated shackles.

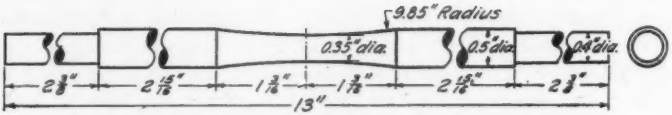
Charpy impact tests were made on a Sauveur and Boylston 30 meter-kilogram testing machine. Repeated-impact tests were made on a special double-hammer machine built in the shops of the department of Theoretical and Applied Mechanics.

The fatigue tests were all made on rotating-beam testing machines such as those shown in diagram in Fig. 10. These machines subject the specimen to cycles of reversed bending, and the bending moment is uniform between C and D.

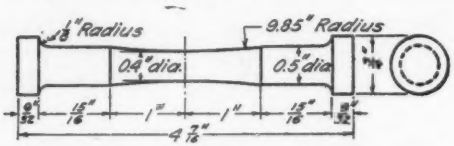
Results of Static Tests and of Brinell Tests

The results of the static tension tests are given in Table 2 and typical stress-strain diagrams are given in Fig. 11. No well-marked proportional elastic limit and no yield point was developed for any tension specimen. The elongation after fracture

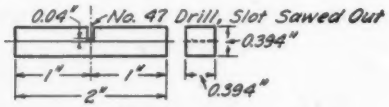
[2] See 1921 report of the British Aeronautical Research Committee.

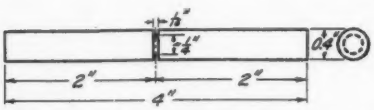


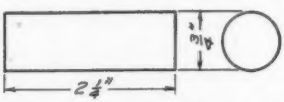
(a)-Rotating-beam Specimen for Fatigue Test



(b)-Specimen for Static Tension Test



(c)-Specimen for Charpy Impact Test

(d)-Specimen for Repeated-impact Test



(e)-Specimen for Static Compression Test

FIG. 8—SPECIMENS FOR STATIC TESTS

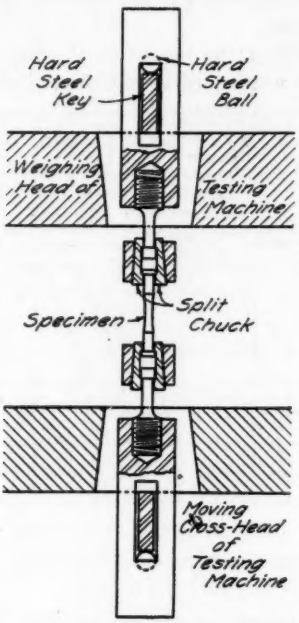


FIG. 9—ROBERTSON SHACKLES, USED IN TENSION TEST DESIGNED TO MINIMIZE FLEXURAL ACTION ON SPECIMENS

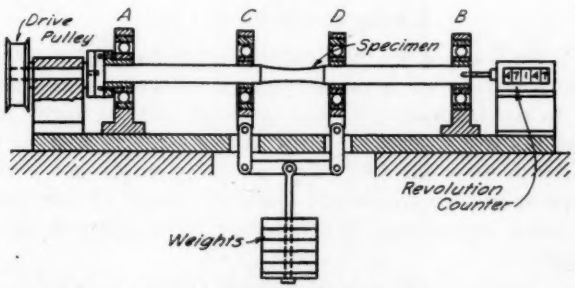


FIG. 10—DIAGRAM SHOWING SPECIMEN IN ROTATING BEAM TESTING MACHINE

and the reduction of area for tension test specimens were too small to be measured.

Table 2 also gives the results of the Brinell hardness tests. In the Brinell tests a standard 10-millimeter ball was used, but the

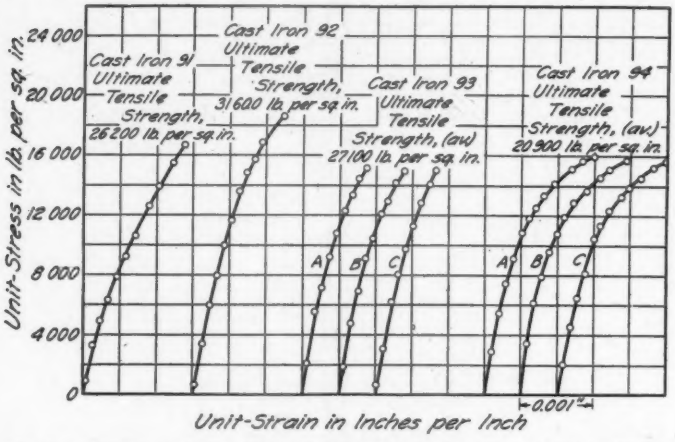


FIG. 11—TYPICAL STRESS-STRAIN (S-N) DIAGRAMS OF STATIC TENSION TESTS OF TABLE 2

load used was 1,000 kilograms. The Brinell number for a given diameter of impression was taken as one-third that given in the U. S. Bureau of Standards reduction tables for a 3,000 kilogram load.

Charpy Notched-Bar Tests

Table 2 also gives the Charpy notched-bar values obtained. Each value reported is the average of results of tests on from four to six specimens. It will be noted that, as might be expected for cast iron, the Charpy values are very low, as compared with those for steel, with the exception of cast iron, 92. Charpy values for normalized machine steel of 14 foot-pounds, and for a heat-treated alloy steel of 45 foot-pounds are not unusual.

Results of Fatigue Tests

The results of fatigue tests of any metals can be best shown by a diagram in which values of computed stress are

Table 2

RESULTS OF TENSION TESTS, COMPRESSION TESTS, CHARPY TESTS, REPEATED-IMPACT TESTS, BRINELL TESTS, AND FATIGUE TESTS OF CAST IRON

Cast Iron, Lab. No.	Static Tension Tests, Pounds Per Square Inch			Ultimate Compressive Strength, Pounds Per Square Inch	Charpy Tests (Notched-Bar), Foot Pounds	Repeated-Impact Tests, Number of Double Blows	Brinell Number	Fatigue Tests*	
	Proportional Elastic Limit	Yield Point	Ultimate Tensile Strength					Endurance Limit, Pounds Per Square Inch	Endurance Ratio†
91	Not clearly defined.		26,200	96,000	4.0	1	162	12,000	0.46
92	Not clearly defined.		31,600	111,000	11.8	1	148	10,500	0.33
93A	Not clearly defined.		28,100	94,000	2.7	1	138	10,000	0.36
93B	Not clearly defined.		25,300	85,000	2.2	1	132	9,000	0.36
93C	Not clearly defined.		28,000	87,300	2.5	2	139	10,000	0.36
94A	Not clearly defined.		21,400	82,500	1.6	3	89	7,000	0.33
94B	Not clearly defined.		20,700	83,500	1.6	4	91	7,200	0.35
94C	Not clearly defined.		20,500	82,000	1.5	4	88	7,800	0.38

*All fatigue tests were made on rotating-beam testing machines.
†The endurance ratio is the ratio of endurance limit to ultimate tensile strength.

plotted as ordinates and values of number of cycles of stress required to cause fracture are plotted as abscissas. Such a diagram is known as *S-N* diagram or stress-cycle diagram. Fig. 12 shows the *S-N* diagrams for the fatigue tests of cast iron. They are plotted to logarithmic coordinates, which have been found convenient to use, but which have no other special significance. It will be noted that the *S-N* diagrams all appear to become horizontal. For a stress less than that for which the

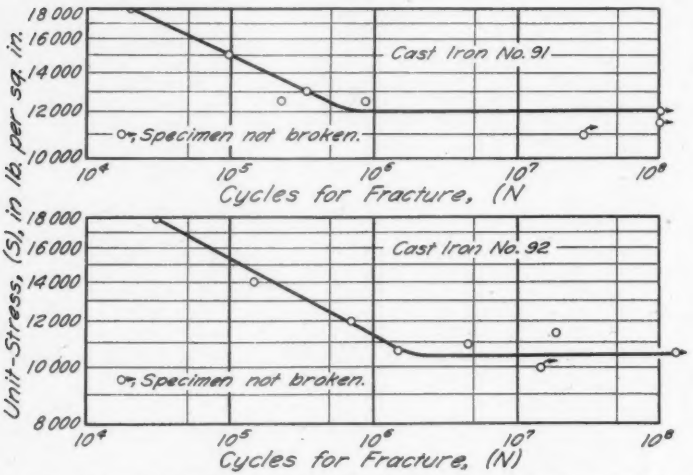


FIG. 12A—S-N DIAGRAMS FOR THE FATIGUE TESTS OF CAST IRONS No. 91 AND No. 92

diagram becomes horizontal, so far as can be seen, the metal is able to withstand an indefinitely large number of cycles of stress. This limiting stress corresponding to the horizontal part of the diagram is called the ***endurance limit*** or the ***fatigue limit***, and is regarded as the best index of the ability of the metal to withstand repeated stress. The results of the fatigue tests are also given in **Table 2.**

For wrought iron and wrought steel the endurance limit is usually found at about one-half of the ultimate tensile strength. It will be noted that for the cast irons tested the endurance limit was found distinctly below this ratio.

Several series of special tests were made. Specimens of cast iron tested under cycles of stress not completely reversed but varying from zero to a maximum gave an endurance limit about 40 per cent greater than the endurance limit under completely reversed stress.

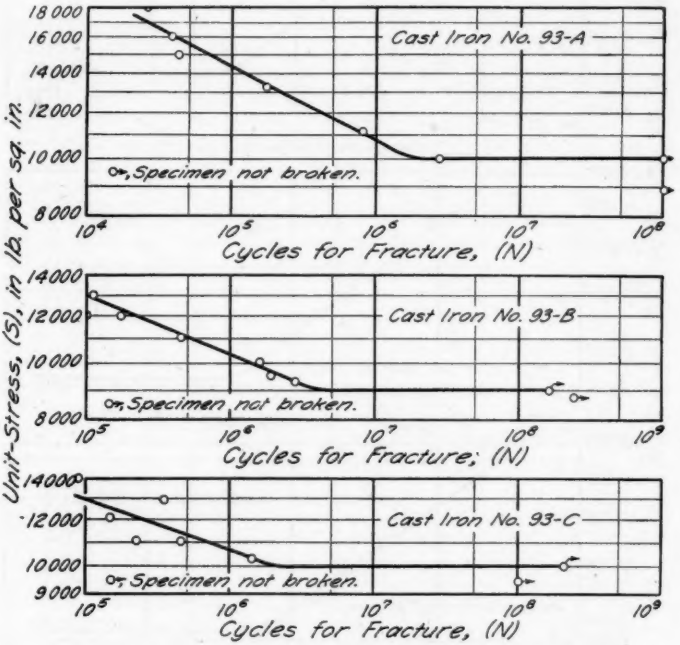


FIG. 12B—S-N DIAGRAMS FOR FATIGUE TESTS OF CAST IRONS No. 93A, B, AND C

Specimens of cast iron in which sharp notches had been turned were tested under reversed bending, and the endurance limit of such specimens was but little less than the endurance limit of cast iron specimens without sharp notches. For steel specimens, especially for heat-treated alloy specimens, the relative effect of notches is much higher than for cast iron; in other words, the graphite flakes and other inherent irregularities of

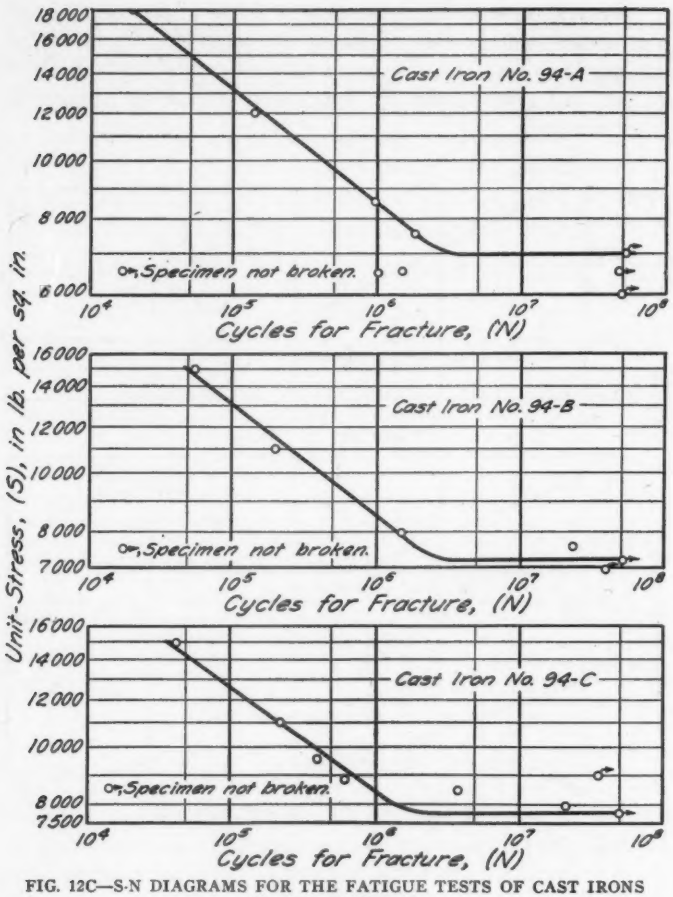

Unit-Stress, (S), in lb. per sq. in.
Cast Iron No. 94-A
Specimen not broken.
Cycles for Fracture, (N)
Cast Iron No. 94-B
Specimen not broken.
Cycles for Fracture, (N)
Cast Iron No. 94-C
Specimen not broken.
Cycles for Fracture, (N)

FIG. 12C—S-N DIAGRAMS FOR THE FATIGUE TESTS OF CAST IRONS No. 94A, B, AND C

structure in cast iron seem to weaken it so much that such additional damage as is caused by notches is not very serious.

A few fatigue tests of cast iron were made at elevated temperatures. The fatigue strength did not show any appreciable falling off up to a temperature of 600 degrees Fahr.

The outstanding result for this short investigation is that

each of four lots of cast iron tested showed a well-defined fatigue limit, although this limit was low, both in pounds per square inch and in comparison with the static tensile strength.

Discussion

J. W. Bolton: We have had the opportunity of listening to a mighty good paper, on a subject that is new to us. Just one point that was of quite a bit of interest to me and perhaps will be to some of the others of you, to note the exceptional resistance of cast iron, both in the short time, high temperature tests, in the fatigue tests, and in the so-called flow or creep tests, as compared to steels. Whereas the authors find that at room temperatures the fatigue endurance limit is something like one-third that of the ultimate strength in the case of cast iron and something like one-half in the case of steel, as I remember charts of steel from work with steel at high temperatures, it seems to me that this condition is reversed in the cast iron, it seems, at least, to hold up somewhat better at high temperatures, compared to its real strength, than steel.

J. T. MacKenzie: I want to congratulate the authors on this paper, which I think is a very valuable contribution. I hope they will continue the good work on cast iron and extend it a little further. I also want to thank them for their remarks on tensile tests of cast iron. It doesn't seem to be generally recognized how far off a simple tensile test can be in cast iron. We run into that all the time, especially with thin walls of cast iron pipe. Some fellow cuts out a strip about an inch wide, 12 inches long, and takes a pair of V-grips and jams them on, pulls it in two and says, "Ten thousand pounds tensile strength."

I would like to comment, also on the excellent stress-strain curves that Professor Moore has given us in tensile strength. It is unfortunate that they couldn't carry those on out to failure.

I would like to call Professor Moore's attention to the work of the Japanese investigators, recently published in the Mechanical Engineers' Society of Japan, showing that cast iron takes a permanent set for practically any load. If you take it up to 500 pounds, the strain gauge does not go back to zero, but a certain, small, permanent set takes place. Then you can carry it to 500 and back to zero and 500 and back to zero it will not stretch any more to speak of as long as you stay within those limits, but if you take it then from zero to 1,000, it will take an additional permanent set, and you can reverse from zero to 1,000 for practically any number of times with no further set. Each time you increase the load it will take an additional permanent set.

S. W. Lyon: It may be said in general, that sharp fillets, threads, and grooves as imposed on machine elements, markedly lower their fatigue strength, this lowering being due to stress concentration. A. A. Griffith by theoretical methods has worked out the weakening effect of grooves of

various dimensions, assuming an ideal material of infinite divisibility and perfect homogeneity. Although these values indicate a severity of effect greater than obtained using any known material, they are of service as a basis for comparison.

Previous results obtained from tests on various grades of steel have indicated that the greatest weakening effect of grooves occurred with the more brittle material. This led to the explanation that ductility was the controlling factor and that the redistribution of stress in the more ductile materials caused them to be less effected by grooves. It was therefore thought that the effect of grooves on cast iron, which is in the usual sense a brittle material, would be large.

Fatigue tests were made on specimens of cast iron 93A with grooves imposed. Contrary to expectations, the results of these tests showed that the effect of grooves on cast iron was small, the weakening effect being less than 10 per cent for the most severe groove. A two-fold explanation of these results is offered.

First: In keeping with the results of the understressing tests described by Professor Moore and the slide showing slip lines there appears to be a quality of strain adjustability or "secondary ductility" in cast iron that has been previously overlooked.

Second: Considering graphite flakes and inclusions as inherent defects, and the grooves as imposed defects, then the relative difference in size between imposed defects and inherent defcts in cast iron is small in comparison to those in steel, remembering that the imposed defect (the groove) is the same size in both. The point here is that the addition of the groove in cast iron more nearly resolves itself into the addition of another inherent defect than in the case of steel, with consequent lesser effect. By analogy, the addition of one more small hole drilled in a plate containing a number of small holes would weaken it less than the addition of a large hole to another plate of the same sizes with no holes.

The Cause of Variations in Pig Iron Qualities

By R. S. McCaffery,* Madison, Wis.

That certain irons possess definite properties quite different from other irons of exactly the same chemical composition has been noted for a long time, and for years pig irons from some furnaces have had such a reputation for possessing desirable qualities that they have commanded a higher than average price on the market. Buyers have been willing to pay the advanced price because they believed they were getting some thing or property in these irons which they did not obtain in other irons.

Theories Advanced to Account for Variations

Among technical men at the present time, the belief that one iron has properties different from another iron of the same chemical composition is very generally accepted as a fact and explanations have been offered to account for the differences. Generally two major theories have been advanced, which have been called the "oxygen" theory and the "rare elements" theory. The names are nearly self-explanatory. The arguments pro and con concerning these theories have been warmly supported and a considerable literature has come into being as a result.

More lately, Fletcher[1] in his exchange paper developed some ideas which seem to have great merit and the work of Piwowarsky[2] and his associates in their study of cast irons of great strength have added additional information on this general subject. This present paper is presented merely as the statement of a theory as to the cause of variation in the qualities of iron, which it is believed accords with the observed facts. It is in

*Professor, College of Engineering and Mechanics, University of Wisconsin.

[1] Fletcher, J. E., *Some Fundamental Relationships in Cast Iron, Wrought and Steel Manufacture*, Trans. Amer. Foundrymen's Assoc., vol. 33, pp. 6-34.

[2] Piwowarsky, E., *Progress in Production of High-Test Cast Iron*, Trans. Amer. Foundrymen's Assoc., vol. 34, pp. 914-981.

no wise a report of experimental research but it is the result of careful study of the problem and believed to be in accord with scientific principles. To the writer at least, it does not require so expansive an imagination as do the older theories.

Pig iron or cast iron will always be found on chemical analysis to contain iron and manganese and carbon, silicon, sulphur and phosphorus. With the exception of part of the iron and carbon which may exist in the pig iron in the elemental form as ferrite and graphite, all the commoner metallic constituents of the pig iron form compounds with the non-metallic constituents which may be present and binary compounds like carbide of iron, carbide of manganese, silicide of iron, silicide of manganese, sulphide of iron, sulphide of manganese, phosphide of iron and phosphide of manganese as well as possible compounds more complex than binaries, may be present in the iron.

Conditions in a Blast Furnace Not Uniform

In a blast furnace producing pig iron, the conditions are not uniform at any one time in the furnace nor are they uniform from day to day, and when two blast furnaces are compared the lack of uniformity becomes more apparent. In any horizontal section of a blast furnace, there is considerable variation in temperature and there is not a proportional change of temperature between the corresponding points in any two different horizontal sections. The result of this is that along any vertical line inside of a blast furnace there is at some fixed time a definite temperature gradient which is different from the temperature gradient along any other vertical line at the same time. If a particle of ore that was charged into the top of the furnace descended through the furnace along one of these lines it would pass along a temperature gradient quite different to what a second particle would be subjected to along another path down the furnace. When the temperature gradients may be so different in various paths through one furnace, a still greater variety of temperature gradients are to be expected in two furnaces.

All chemical reactions have a definite free energy at a given temperature and with some reactions the free energy increases

as the temperature rises, while with other reactions the free energy decreases with rising temperature. This means that all chemical reactions have a velocity that varies with the temperature and that chemical affinities vary with temperature.

Reactions May Vary at Different Temperatures

It means, too, that when a number of chemical reactions are taking place simultaneously at a given temperature one reaction will predominate over the others, while at a different temperature another reaction will predominate, although a number of reactions may all be taking place at the same time to a greater or lesser degree. Many of you are familiar with the fact that in normal Bessemer blows, the silicon is first oxidized and afterwards the carbon is blown out; whereas, in a blow that starts at an initially higher temperature, the silicon is eliminated after the carbon. Similarly in a basic open hearth heat, normally the phosphorus is taken out first and the heat finished on carbon but by beginning a heat at a high initial temperature, the carbon may be removed first and the phosphorus may remain to the last. In malleable air furnace heats, too, the order of elimination of impurities from the bath may be varied by control of the bath temperatures.

The importance of this point and its full significance is emphasized by reference to Fig. 1. Two baths of molten metal, both of the same initial temperature and compound composition and in each of which reactions are taking place, are heated. In the same total time, both reach the same final temperature, one passing along the temperature gradient A while the other passes along B. Let us consider what is happening at the time represented by the line *m, n.* In the bath A, a number of reactions are taking place at the same time and each is producing its own end product. All of them are progressing at different rates, and one reaction is predominating over the others. In the bath B, at the point *n,* the same reactions are occurring ***but at different rates because the temperature is lower*** than at *m* in bath A and a different reaction may be predominating. In any event, since the rates of reaction are different at *m* and *n,* the bath compositions are different. Similarly at other equal time points along A and B, the reactions proceed at different rates till the point X is reached,

which is at the same time in each bath but by proceeding along a different temperature gradient. The result is, the two baths now at temperature X are not of the same compound composition although both started with the same composition and in the same time reached the same final temperature. It is assumed that the heating of the metal baths was carried on at an economic or commercial rate and that equilibrium was never attained, or in ordinary words, common practice in heating was followed.

The fact that two molten metal baths may reach the same temperature in the same time but be of different compound composition is a point of considerable importance that is overlooked

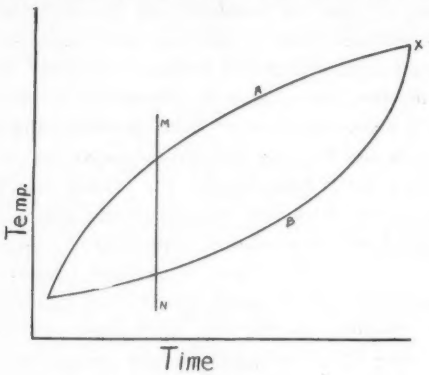


FIG. 1

in plants, and it may account for variations in the properties of heats of the same chemical composition that are explained usually in various other ways.

Reactions in Blast Furnace Vary With Change of Temperature

In the blast furnace, there is a series of reactions taking place. The velocities of these reactions change with the furnace temperature. In the passage of the particles down the furnace the temperature rises and the order of the reactions keeps changing. All parts of the charge are not carried down the shaft along the same temperature gradient, so that the reactions are not taking place uniformly at one place in the furnace and uniformity of conditions is not maintained. Then, too, there are

irregularities in the operation of any blast furnace due to the changes that are taking place in various operating factors, and the same *average* temperature gradient does not persist from hour to hour, let alone from day to day. The reactions that take place in the furnace produce the various carbides, silicides, sulphides and phosphides of iron and manganese. It can be seen, then, that along different temperature gradients, one kind of iron of a definite compound composition may be produced by passage along one temperature path while iron of different compound composition results from taking another path. It may be, too, that while the compound composition is different in the two cases, the chemical composition may be the same; for example, the carbon may be present all as carbide and in one iron the iron carbide might be high and the manganese carbide might be low while in the second the iron carbide might be low and the manganese carbide high, although the carbon might remain exactly the same in the two irons.

Properties of Iron Partly Due to Compound Composition

The properties of the iron are not entirely due directly to its chemical composition, but its compound composition may profoundly influence its properties.

If two pig irons are of the composition indicated in Table 1 they may have the same chemical composition as shown in Table 2; but, because their compound composition is different (although the chemical analysis is the same), the properties of the two will be different.

Table 1

	No. 1 Iron	No. 2 Iron
Iron Carbide	a%	m%
Iron Silicide	b%	n%
Iron Sulphide	c%	p%
Iron Phosphide	d%	q%
Manganese Carbide	e%	r%
Manganese Silicide	f%	s%
Manganese Sulphide	g%	t%
Manganese Phosphide	h%	u%

Table 2

	No. 1 Iron	No. 2 Iron
Iron	J%	J%
Manganese	K%	K%
Carbon	L%	L%
Silicon	M%	M%
Sulphur	N%	N%
Phosphorus	P%	P%

It may be objected that the amounts of some of the compounds which might be present will be small and therefore their influence on the properties of the iron will be slight. It is known, however, that relatively small amounts of compounds will affect the properties of steel to an important extent. The presence of sulphur as a compound of iron, as FeS, or of manganese, as MnS, is a case in point when the higher melting point of the manganese sulphide causes it to separate in grain interiors instead of on grain boundaries as does the lower melting point iron sulphide and it thus changes materially the brittleness of the steel. The amount of these compounds, too, will be larger than the content of "rare elements" or of "oxygen" or other gases which has satisfied the supporters of some of the other theories.

The theory outlined in this paper has been reduced to its simplest form; for one thing, the effect of solubility of constituents has not been considered. In its most elementary outline, it indicates how the relative amounts of compounds which may be present in pig iron might change, due to variation in blast furnace operating conditions. When we consider that some of these compounds may vary by considerable percentages, the variation in the properties of pig irons of similar analysis but produced under different conditions does not seem so extraordinary. It has been repeatedly noted that certain irons retain their characteristics to a greater or less extent after re-melting a number of times. If this be so, it gives additional support to the proposed new theory. Certain temperature conditions in the blast furnace cause some reaction to predominate at definite temperatures and produce definite end products or compounds in the iron. If then on re-melting, this temperature range in which the compounds were formed in the blast furnace is not attained, or if it should be reached but only for a short time, then the compounds formed at the higher temperatures persist, and the iron only liquefies. On cooling and solidifying again, it has the same or approximately the same compound composition and retains, therefore, to a greater or less extent, its original properties. The theory advanced in this paper does not attempt to ascribe all the properties of the iron to the compounds which may be present.

The alloy structure is most important. There are other things, however, besides what might be called the gross structure which may profoundly influence properties. It is suggested that as in the ordinary processes of manufacture, there are variable factors which greatly change the compound composition, that possibly this may account for observed differences in pig iron qualities.

The writer is using the theory tentatively to outline experimental work and is not so committed to it that the results of this experimental work may not cause him to throw it overboard or to modify it considerably, but as a working tool it seems to have some use.

Discussion

J. H. Lansing: I was interested in the points that Professor McCaffery brought out, particularly on the different methods of bringing down a heat and getting the same up to temperature. In one case, if you melt slowly, the presumption is that your resultant heat will be rather low in silicon and manganese and possibly have fairly good carbon. If the reverse is the case, if you melt fast under the high temperature, the presumption is that your silicon and manganese will be up somewhat more than your carbon. The point that I was bringing out and asking Prof. McCaffery for his ideas, was whether or not in correcting these conditions, that is, by making additions of petroleum coke or ferro-silicon or ferromanganese, whatever is required, whether or not the compound composition would not be largely corrected?

R. S. McCaffery: Part of that question I can answer and part I cannot. I can answer in the first place that it is perfectly true, that silicon and manganese will be eliminated at a lower temperature and carbon at a higher temperature, and that if you start in a higher temperature the carbon will go first, leaving the silicon and manganese behind, and when I say that, don't mistake me, that I think those reactions are cut short very abruptly at any one temperature, because I don't believe that, but I believe that the rate is greater at one temperature than another, I mean generally that at a low temperature the silicon will oxidize more rapidly than the carbon will, whereas the carbon will oxidize more readily than silicon at a higher temperature.

The second part of the question I can't answer, for this reason: if you add ferro-silicon I would presume that the silicon was mostly iron silicide, and I am not sure in any particular iron just what the proportion of iron silicide and manganese silicide is, I can't say, either, for lack of experimental data just what the desirable amount of iron silicide and manganese silicide is. That is a thing that would have to be determined, so far as I can see, in the future.

F. W. BAUER: If the fact is that the ferro-silicon or ferro-manganese when introduced is a silicide or a manganese combination with iron, you are not introducing the element yourself. It is already combined as an alloy. Would not that help you to give us an idea to answer that question without much experimentation? You understand, this manganese and silicon are already combined in the alloy before it is added, now you are adding it as a compound.

R. S. MCCAFFERY: I thought I answered that. Perhaps I should state my understanding of Mr. Lansing's question, so that we may be sure we are talking to the same subject. I understand him to say that if, for any reason, when he proceeded along one temperature gradient and got certain eliminations, and that the final temperature of his bath was not the desirable, the final composition of the bath was not the desirable composition, then could he bring it to that desired composition by the addition of ferro-alloys? Now, I quite understand that in ferro-silicon the silicon is present as silicide, but on the other hand, when you are working in a bath of molten iron, like a malleable bath, I am not at all certain just what the combination of the silicon is under those conditions. It may be by a simply binary compound of silicon that is present, or it may be a more complex one than that, and I could not see how I could answer his question definitely, so far as that was concerned, because I could not know what the combinations of silicon would be in the one case, and whether he would be adding silicon combinations that were exactly like those in the bath. If they were not the same combinations as were present in the bath they would not have the same compound composition and they'd have different properties.

E. J. LOWRY: That is a very fine paper that the author has given us. It gives a great deal of food for thought. There are so many things that have been written and so many processes established to bear out the theory that it is almost undebatable, but in order to get a discussion of it I wonder if the author could tell me if by changing the constitution of the slag in the blast furnace it would react on some of the variations in the pig iron? In other words, in making acid steel, you run an acid slag; making basic steel you run a basic slag. The two steels are different in nature. In blast furnace you can run acid, neutral or basic slag. It has been my experience that as you vary the slag constitution, so you vary the quality of the pig iron. That slag also varies the form of the carbon. In other words, the acid slag tends to give you more the true nature of the primary form of graphite, whereas the real basic slag tends to give you the carbon that approaches the secondary form. You have cited Piowarsky. Piowarsky tells you carbon is refractory and persist in the iron unless it is superheated. Only yesterday it was shown that even though the superheat was carried to extremely high temperatures, all of those nucleii forms of graphite were not eliminated.

R. S. MCCAFFERY: With reference to blast furnace slags, it seems to me that the main operating factor on which you regulate your iron blast furnace is the slag. You determine its composition and you operate your

furnace as indicated by how it comes from the furnace and how it flows and how it cools. If your slag is not sufficiently fluid you make it fluid and you regulate the temperature of your furnace by regulating your slag and making it the desirable slag that is economically advisable. Then when you operate in that way you change your furnace temperatures. Then changing your furnace temperatures, the iron will take care of itself. Changing your furnace temperature you change the order of reaction. I don't think you go and change the temperature of your furnace and then go and change your slag composition and go to it in that order. I think that you go to your slag and you regulate your furnace operation on your slag and make that operate in the way that you desire, increase or decrease the furnace temperature, depending on the way your slag flows. I know that ordinarily if the slag is not flowing from the furnace properly they will change the coke ratio, for example. When they put in blanks of coke, and they do that to change the temperature of the furnace, then when they change the temperature of the furnace they will change the order of reactions that take place. As I see it, it goes back to temperature control entirely, and as a matter of fact, there are only two things that influence chemical reactions: temperature and pressure. You might as well realize that in the beginning. There are only two factors that influence the reactions, temperature and pressure. Pressure remains the same, remains constant, so it is the temperature that does the work.

E. J. Lowry: In New York we have been operating coke blast furnaces on basic slags. Now we have reversed and have been operating two months on acid slags. We find there is a difference in the nature of the iron.

R. S. McCaffery: What is the difference in your furnace temperature?

E. J. Lowry: About 150 degrees higher.

R. S. McCaffery: How do you determine that?

E. J. Lowry: By optical pyrometer.

R. S. McCaffery: A 100 degrees in temperature will account for a great difference in the rate at which reactions take place, and if you admit even just taking the temperature and it must have been outside the furnace or you would not have had to apply a correction, if you get 100 degrees difference in the temperature outside, then there must be at least 100 degrees inside. It still seems to me temperature is the factor that controls and not the composition of the slag. I realize that the slag has to be changed, and ordinarily I think you proceed to make the slag that is economically desirable in the particular place. If you would make 100 degree difference in the temperature outside the furnace that would be an amount that would produce a very great variation in the rate of reactions and would account for the variation in the amounts of compounds and the variation of properties, as I see it.

E. J. Lowry: From this furnace in New York state we took samples at the furnace, taking just a water quench sample. We took it in the ladle.

Then at the pig machine. The total carbons varied from 4.16 to 4.40 at the tap spout, in the final pig iron it varied from 3.9 to 4 per cent. That loss in carbon was the same—no, it was greater in the basic than in the acid. That is right. It is a question of temperature.

F. W. BAUER: This is one of the best papers I have heard this morning. It has been so very open minded. We have listened to a number of papers this week that have had a very practical turn of mind, and we have also listened to a number of other papers that have been very technical and of very great value, but it occurs to me that Mr. McCaffery has approached this question in such an open minded, practical sort of way, to link in a great many of the practical things that have been said this week, with those of a chemical or a technical nature, and the microscopic. He has gone into the question of the analysis of the various compounds, which we do know exist, the carbon in the various combinations, and the phosphorus and the manganese. If these can be determined chemically and with the microscope, it would seem as though the door were opening so that we may arrive somewhere to answer the question of that committee that we discussed the other day. We all know that pig iron causes some trouble once in a while. Of course, those that have produced pig iron think the foundrymen spoil it more than the blast furnace does, but the fact remains we have to use the iron as it is produced. There has been no attempt in this paper to tell the blast furnace man how to do these things, and I think that is a commendable thing, because when you hear a technical paper, as we have heard this week, trying to outline in advance the control of a blast furnace to produce iron with a certain amount of cementite and pearlite and these various combinations, you are simply getting into the way distant place that you are never going to reach. In the first place you start with the raw material like ore, and you have to control your furnace, as Prof. McCaffery says, by the control of your slag and temperatures to produce results, and to keep the furnace operating. A furnace chills very easily and you want to get a certain kind of iron analysis and you must control the operation, and it can't be done, and at the same time produce iron of a certain microscopic and chemical analysis combined. I just wanted to say further that if Prof. McCaffery would keep up this work and make an effort to help this committee, I think it would be very valuable. This idea that pig iron is causing imperfect results at certain points under certain cupola conditions is not always one we can follow through.

MR. BURZ: There is just one thing I would like to say along the line Mr. Lansing referred to, and that is the matter of doping of heats. We do not have real facts on this proposition, merely impressions, but it does seem that if a heat of malleable is very hot and the oxidation losses have been great, your silicon and carbon are low. If you recarbonize that heat, add ferro-silicon, possibly spiegel, if the heat is hot our experience has been that the end results or the quality of the castings are very good, and contrary, if the heat is not hot, so to speak, when you make additions you

don't seem to get the same results. Now, quite recently we had a heat of malleable where the silicon, carbon and manganese reduction was very great. The heat was very, very hot when we made our additions, and we got the best test bars out of that heat that we have ever produced in our foundry. We got a tensile strength of about 62,500 pounds and an elongation of 25 per cent. The final silicon carbon on that heat was .99 silicon and 2.05 carbon. This matter of temperature that Prof. McCaffery referred to I feel, in producing both gray iron and malleable, certainly is an important factor.

Joint Committee on Foundry Refractories
Report of Sub-Committee on Malleable Furnace Refractories

Your sub-committee on Refractories for the malleable industry after further consideration of its report as presented at the Detroit meeting of the American Foundrymen's Association, recommends to the Joint Committee that certain sizes and shapes of refractories be approved as tentative standards for the malleable industry. Full discussion of reasons are given in the Detroit report. The recommendations are listed below:

1. *Door Opening Tiles.*

Note: Over the skimming and sampling holes in side walls the majority of foundries use No. 1 and 2 nine inch arch and wedge brick to make the arches. However, quite a few foundries are using large tile brick over these openings with good results. This latter practice is strongly recommended because it is easy for the bricklayer to lay a tile whereas it takes a longer time to set an arch.

Recommendation: Your sub-committee recommends that there be adopted as a tentative standard the use of tile of two sizes (see Fig. 1) as follows:

5″x9″x24″ and
5″x13½″x24″

Note: These thicknesses correspond with the standard 9 inch brick, the widths work out for varying wall thicknesses and the length will span any hole opening.

2. *Tap-Out Blocks*

Recommendation: Your sub-committee recommends that there

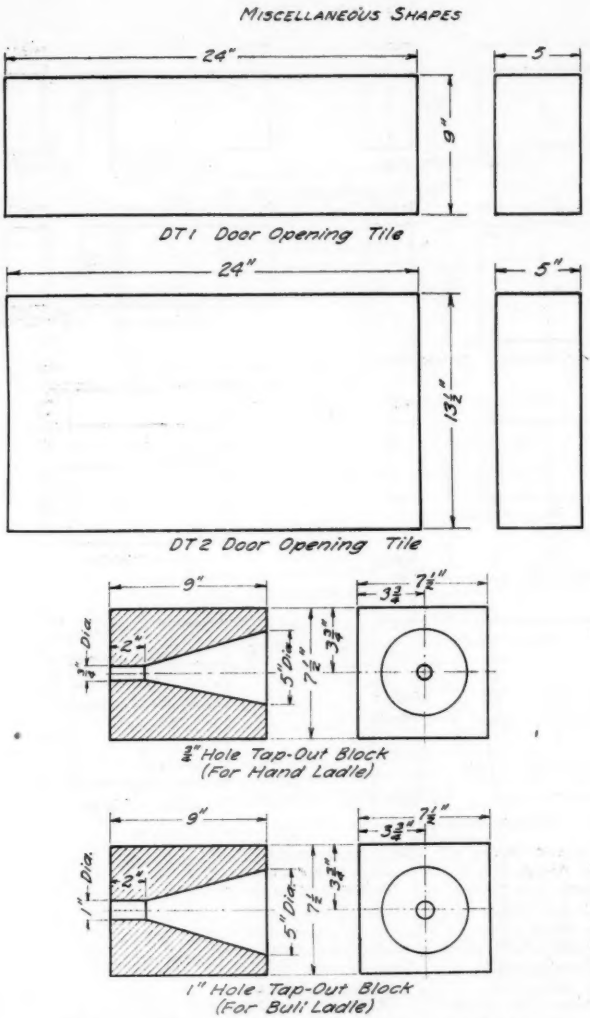
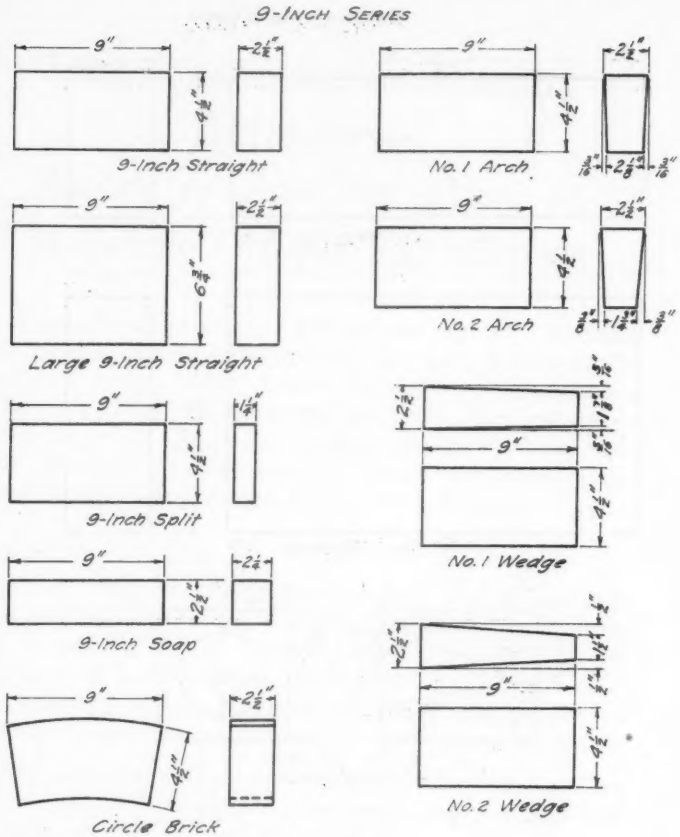


FIG. 1—DOOR OPENING TILE AND TAPOUT BLOCKS



24-in. Circle Brick
24-in. Inside Dia.
12 Bricks to a Circle

36-in. Circle Brick
36-in. Inside Dia.
16 Bricks to a Circle

48-in. Circle Brick
48-in. Inside Dia.
20 Bricks to a Circle

60-in. Circle Brick
60-in. Inside Dia.
24 Bricks to a Circle

72-in. Circle Brick
72-in. Inside Dia.
28 Bricks to a Circle

84-in. Circle Brick
84-in. Inside Dia.
32 Bricks to a Circle

FIG. 2—9-INCH SERIES

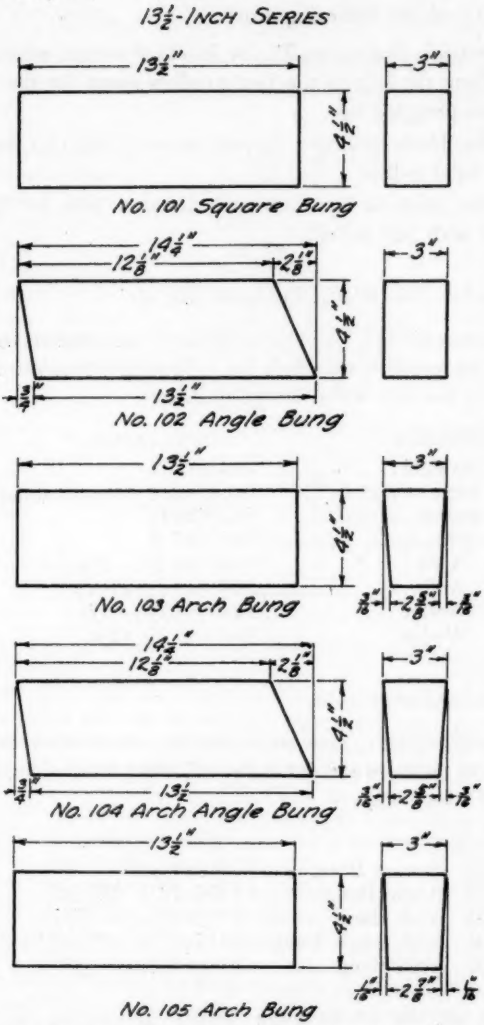


FIG. 3—ANGLE AND ARCH BUNG SHAPES

be adopted as a tentative standard the use of two tap-out blocks (see Fig. 1) of the following sizes:

Outside dimensions 7½ by 7½ by 9 inches, with suitable flare from the hole to the face to allow room for the tapping rod and plugging up.

One block to have a ¾ inch diameter hole for foundries using hand ladles.

One block to have a 1 inch diameter hole for furnaces served with bull ladles.

3. Shapes for Side Walls, Bridge Walls, etc.

Recommendation: Your sub-committee recommends that there be adopted as tentative standards the following dimensioned shapes (see Fig. 2) for side walls, bridge walls, etc.

Classification	*Size in Inches*
9 inch straight	9x4½x2½
9 inch large straight	9x6¾x2½ (for breaking joints)
9 inch soaps	9x2½x2¼
9 inch split	9x4½x1¼
No. 1 Arch	9x4½x(2½—2⅛)
No. 2 Arch	9x4½x(2½x1¾)
No. 1 Wedge	9x4½x(2½—1⅞)
No. 2 Wedge	9x4½x(2½x1½)

4. Shapes for Bungs

Recommendation: Your sub-committee recommends that there be adopted as tentative standards the following dimensioned shapes (see Fig. 3) for bungs.

Classification	*Size in Inches*
No. 101 Square Bung	13½x4½x3
No. 102 Angle Bung	(13½x12⅛)x4½x3
No. 103 Arch Bung	13½x4½x(3—2⅝)
No. 104 Arch Angle Bung	(13½x12⅛)x4½x(3—2⅝)
No. 105 Arch Bung	13½x4½x(3—2⅞)

(Some of the above bung shapes dimensions have been changed from present sizes with classification number remaining unchanged.)

5. Shapes for Stacks

Recommendation: Your sub-committee recommends that there be adopted as tentative standards the following dimensioned shapes for stacks:

Circle Brick	*Size in Inches*
24-inch circle	9x4½x2½
36-inch circle	9x4½x2½
48-inch circle	9x4½x2½
60-inch circle	9x4½x2½
72-inch circle	9x4½x2½
84-inch circle	9x4½x2½
No. 1 Wedge	9x4½x(2½—1⅞)
No. 2 Wedge	9x4½x(2½—1½)

Respectfully submitted,

JAMES R. ALLEN, *Chairman,*
H. M. THOMPSON,
J. H. BIRDSONG.
Sub-Committee on Survey of Refractories in the Malleable Industry.

DISCUSSION

MEMBER: I am going to ask Mr. Allan to tell us the reason for adopting the 9 inch brick.

J. R. ALLAN: We simply took the 9 inch brick series because it was already in effect and it has been in use for a great many years, and it is very well adapted to side wall construction or any place where you might want to use it. We saw no need to change those dimensions, although there have been some suggestions that it would be better if the side walls were constructed of a larger size brick than the regular 9 inch straights.

MEMBER: My only reason for asking was that I knew they had used tap out blocks that were longer than 9 inches.

J. R. ALLAN: You refer to the tap out block?

MEMBER: Yes. I wondered why the committee figured it was not the better idea to tie the tap out block into the outside lining? Was that discussed at all?

MR. ALLAN: It is a little more difficult to get a good tap out block if you make them much longer than 9 inches. You want a good dense, hard brick, and you are getting into long dimensions when you get into 13½ inches if you consider one and a half brick length. The majority of the industry are using tap out blocks anywhere from 5 inches to 7 inches, 8 and or 9 inches long. I can't recall of more than one case in the answers

to the questionnaire where the industry is using anything longer than 9 inches.

C. E. BALES: From the producer's standpoint, the idea of standardization as brought out here is highly desirable. There are a good many reasons for that. If these shapes are adopted, and I certainly hope they will be, because some foundries are already using them, and find they are practical, those shapes could be carried in stock in the plants that manufacture malleable brick, whereas at the present time if you order a special shape brick it takes anywhere from three to six weeks before they are available. These door tile that have been mentioned, I might say that these tentative standards as proposed were not accepted without quite a bit of discussion and argument because some of the consumers had their ideas about it and some of the producers had their ideas, so the standards that have been proposed tentatively ought to be pretty good, and if they are adopted and actually used, why you can get your brick in much less time than you get it now, and we believe you can get a better product at a better cost.

In regard to tap hole block, there must be at least 70 different kinds because one manufacturer had sixty. There are some tap hole blocks that are impossible to make and make so they will give a malleable man good service. One along that line is a 13½-inch block that I have in mind. There is one foundry that buy large blocks. It is impossible to make the blocks without having oil cracks and sand cracks in them, and they invariably fail after one week's operation. The same thing can be said in regard to bung brick, that I said in regard to the door tile, that all manufacturers would carry those bung sizes in stock for you. At the present time there are a good many different sizes of bung brick being produced. Sometimes it is necessary to wait for them unless you have arrangements with your fire brick company to carry a stock. I believe these standards, if they are finally put to use, will enable you to get a better product at a lower cost, and you can get your brick when you want them.

Pickling Solutions for Cleaning Malleable Castings

By F. L. Wolf,* Mansfield, Ohio

Among other commodities which we manufacture there is a full line of malleable castings which are used in connection with the electric railway field and for hardware used in the construction of high tension transmission lines. Castings will average in weight anywhere from a few ounces up to twenty or thirty pounds.

Practically all of our malleable castings are subjected to the hot galvanizing treatment and must, therefore, be perfectly clean and free from scale of any kind. In some cases sand and cores are fused to the castings and often during the annealing process some of the castings are badly oxidized. We find that such castings can be readily cleaned when subjected to the action of a 5 or 6 per cent solution of sulphuric acid for a period of about 35 to 45 minutes, the solution being heated to a temperature of about 140 to 160 degrees Fahr.

If castings carry an unusually large amount of silicate scale, it is well to add about 2 per cent of hydrofluoric acid to the pickling solution.

Castings in the hard iron state, as they come from the foundry, are given a light sand blast so that they can be more easily inspected. They are then sent to the chipping benches, grinders and through the anneal. After the anneal they are given a normalizing treatment. This normalizing treatment is a patented process which we have developed, and prevents malleable castings from becoming brittle after hot galvanizing. The treatment consists in heating the castings to 1250 degrees Fahr. and then quenching. This treatment also helps to break up any scale adhering to the casting. After the above process, the castings are given a thorough sand blasting, a final inspection and trim before going to the galvanizing department. At this point it is

*Technical Director, Ohio Brass Co.

found that about 20 to 25 per cent of the castings are in such condition that they must be pickled and sand blasted before being galvanized.

Our tonnage amounts to about 350 to 400 tons per month, and all of the pickling necessary is done in 4 to 8 small pickling tanks, lead lined and having the dimensions—22 inches wide, 22 inches deep and 9 feet 6 inches long.

A very efficient ventilating system is used to remove the obnoxious fumes from the pickling tanks. The ventilating system is connected to two large capacity ventilating fans which remove 32,000 cubic feet of air per minute, and at no time is there the slightest evidence of fumes in the department. Before the installation of the ventilating system, we had a crew of seven men in the pickle house and the production turned out by them was very small; with eight tanks they handled about 15,000 pounds of castings per day. At the present time, we have two men working on piece work, and they handle 30,000 pounds of castings in a 10 hour shift.

The cost of pickling will now run flat about $1.60 per 1,000 pounds. Costs as follows:

Labor per 1,000 pounds	$0.60
Steam per 1,000 pounds	0.50
Water per 1,000 pounds	0.10
Acid per 1,000 pounds	0.30
Power per 1,000 pounds	0.10
Total per 1,000 pounds	$1.60

These costs, when compared with sand blasting, are a trifle high. Recently we have installed several pressure type sand blast machines using steel grit as an abrasive and feel sure that we will be able to eliminate practically all of the castings from the pickle house as the grit blasting will clean them good enough so that they can go directly to the galvanizing department.

The grit blasting is much more desirable, and also cheaper, than pickling and sand blasting.

After a long series of experiments, we have found that, when the iron sulfate contaminates the bath up to 20 to 25 per cent, the pickling time is doubled. When the iron sulfate content goes

up to about 50 per cent, there is practically no pickling action. The tanks are emptied twice a week.

The disposal of the spent acids is somewhat of a problem and this question has been discussed from time to time with state officials who are interested in the preservation of fish and game. The spent liquor containing the sulfate of iron is more detrimental to fish life than a straight acid solution. There is no method that we know of that is entirely satisfactory to take care of this condition. We run the spent acids into settling tanks and endeavor to crystallize as much as possible of the sulfate before the waste is discharged into a nearby creek.

The tanks used are of cypress lined with ⅛ inch lead, and the stay rods and bolts and nuts are made of alcumite. The pickling boxes which hold the castings when immersed in the tanks are 11⅜ inches long, 7¼ inches wide and 9½ inches deep. These are also built of cypress. They cost about $1.00 each and the average life is about six weeks.

We have been conducting some experiments using boxes made of alcumite which is aluminum bronze, and after nine months' constant use the metal boxes show no deterioration or loss in weight.

Discussion

J. H. Lansing: A question I had in mind is whether or not the special process of heat treating the castings after the anneal did not render the pickling necessary, or a particularly good method, you might say, of cleaning the castings, and that such would not be necessary in the ordinary run of castings as produced. That is, whether such a method would be necessary for the regular run of malleable foundry castings, whether or not, for instance, the author tried out using sand for their sand blast, and found that unsatisfactory.

F. L. Wolf: As I understand the question, you wish to know if the normalizing treatment will increase scale on castings. This treatment merely produces a flash of oxidation on the surface and this is easily removed. We find that the steel grit knocks this flash off easily. Since we have used the normalizing process we have helped our cleaning condition. As the castings come out of the normalizing furnaces they are at red heat and quenched in water. This tends to crack any silica scale and this comes off very easily. After pickling all of our castings are hot galvanized, and naturally they have to be 100 per cent clean. Our specifications are so rigid that we will not allow a galvanized casting to go out that has a bare spot the

size of a pin head. It has to be 100 per cent covered. We have found lately that steel grit in a pressure type machine prepares the surface in great shape for galvanizing.

J. H. LANSING: Do you use that in the case of hard iron castings?

F. L. WOLF: We use sand for blasting the hard iron castings—just blasting enough so the chippers and grinders can inspect castings before annealing.

E. F. WILSON: I'd like to ask Mr. Wolf whether anything has been done on electrolytic pickling? I believe Morris DuKay Thompson worked on that and has a paper on that subject.

F. L. WOLF: I do not know of the electrolytic pickling of iron. We use this scheme for cleaning brass.

E. F. WILSON: That process, as I understand it, is beneficial in the case of burned castings. There is some hydrogen that is in a nascent condition which reduces the oxide to iron. It gives you a very clean metallic surface. This is only from hearsay. I understand the equipment is a bit complex, but in certain cases it might prove advisable.

There is another question I'd like to ask Mr. Wolf. Do you use inhibitors of any kind?

F. L. WOLF: No. We did at one time. We used glutrin.

E. F. WILSON: Why did you cut it out?

F. L. WOLF: We installed an efficient system for ventilating which is more satisfactory. Glutrin does tend to keep down fumes.

E. F. WILSON: Does it cause any trouble, this inhibitor, when you galvanize afterwards?

F. L. WOLF: No. Of course, there is a tendency for malleable iron to become brittle after galvanizing. For years we were at a loss to account for the reason. We discovered this scheme of heat treating, or normalizing. Just what takes place, I cannot tell you, excepting that I do know it does the trick. Looking at the specimen under a microscope the structure is the same before treatment and afterwards. You cannot detect any difference. The fracture you find in the brittle material will follow the grain boundaries, while in the ductile material the fracture goes through the crystal. There is one theory that in pickling you have hydrogen absorption and that has a tendency to make the iron ductile, but we have disproved this in the case of malleable castings.

The Improvement of Aluminum Bronze as an Engineering Material

By Dr. R. C. Reader,* Birmingham, England

The aluminum copper alloy containing usually 10 per cent aluminum, and commonly known as aluminum bronze, is an alloy whose useful properties are only just beginning to be fully realized and appreciated, and when they are better known they will ensure for the alloy a much wider field than it has at the present time. There are, however, one or two difficulties that are encountered with the use of this alloy, and because of this the writer considered that a paper dealing with the various methods of avoiding these difficulties, as well as with the methods of still further improving the alloy, might be of assistance, and he has therefore prepared this paper and hopes that it will be of assistance as well as of some value to those foundrymen who make and use aluminum bronze.

During the last twenty years many papers have been written on this alloy dealing with the large amount of experimental work which has been carried out on it. In this connection mention may be made of the work of Carpenter and Edwards, and Rosenhain and Lantsberry who worked on the mechanical properties, and of Curry and Stockdale who worked on the equilibrium diagram. Since the very comprehensive work of Carpenter and Edwards in 1907 papers have appeared at frequent intervals dealing with various properties of aluminum bronze, and in this group may be mentioned the works of Corse, Comstock, Rickard, Whittaker and others.

The chief inference to be drawn from the above published works on aluminum bronze is that it possesses many properties superior to those of other non-ferrous alloys, and it is now known that these useful properties of the plain 10 per cent aluminum

*Metallurgist.

bronze can be further improved and troubles avoided by the following methods:

1. The addition of one or more extra elements.
2. The use of chill castings instead of sand castings.
3. Correct casting temperature, and in the case of die casting, a correct mold temperature.
4. Correct mold design and correct position of the casting in the mold.
5. Correct position of the feeder head, and
6. The employment of heat treatment.

The mechanical and physical properties of aluminum bronze can be varied more or less considerably by any one of the factors enumerated above, and so it is intended to deal with each of these points in turn. In so doing, however, the writer wishes to make it clear that he is drawing freely on the work of others. He is, however, able to confirm the results of all these from his own work and observations.

1. *The Influence of Added Elements*

The normal 10 per cent aluminum bronze in the chill cast state possesses the following mechanical properties: tensile strength up to 36 tons per square inch, a yield point of 12 to 13 tons per square inch, with an elongation of 30 to 35 per cent on 2 inch. These properties alone are sufficient to indicate the usefulness of the alloy for constructional parts, even more so when it is remembered that these properties are accompanied with a high resistance to fatigue. This latter property should be kept in mind when comparing this alloy with other non-ferrous high tensile alloys, which may approach it in tensile strength but always fall short in fatigue tests.

Although 10 per cent aluminum bronze is a suitable alloy for many purposes, its mechanical and physical properties can be improved by the addition of one or more elements, such as iron, nickel, or manganese. Advantageous results in some respects may be obtained by the addition of 1 to 2 per cent of lead, such as antifrictional properties, though the effect on the strength of the

alloy is not pronounced. Additions of tin and of silicon should be avoided as they reduce the ductility of the alloy very considerably.

(a) *Effects of Addition of Iron*

Iron added to aluminum bronze improves the properties in two ways. Firstly, it increases the resistance of the alloy to attack by some of the acids,[1] and it also raises the mechanical properties of the alloy. It has been found by various investigators that maximum mechanical properties are obtained by the addition of about 3 per cent iron, when the alloy possesses a tensile strength of about 40 tons per square inch, a yield point of about 14 tons per square inch, and an elongation of 20 per cent. Further additions of iron should be avoided as they bring about reduced ductility combined with a possibility of unsoundness.

Aluminum bronzes containing up to 3 per cent iron are suitable alloys for die casting purposes, when slightly higher mechanical properties than those given above can be obtained, due to the greater chilling effect in this method of casting. The alloy is one also eminently suitable for hot working, and in this field it has unlimited possibilities, since it is extremely ductile at high temperatures.

Beneficial results also follow the addition of iron because the presence of iron imparts a fine crystal structure to the alloy, by providing a large number of nuclei from which crystallization starts. This fact is of extreme importance since it greatly minimizes the effects of "self-annealing." This point is mentioned later.

A useful aluminum bronze alloy containing iron is: iron 2 to 3 per cent, aluminum 10 per cent, and the remainder copper.

(b) *Effects of Addition of Nickel*

Additions of nickel to aluminum bronze affect the properties in various ways, some advantageous and other disadvantageous. For example, the addition of 7 per cent nickel to 10 per cent aluminum bronze raises the tensile strength to its maximum of

[1] Corse, W. M., *Aluminum Bronze—An Acid Resisting Material*, Trans. A. S. S. T., 1926.

about 42 tons per square inch, but this rise is accompanied by a big decrease in ductility, and this restricts the use of this alloy for some purposes.

One of the chief advantages brought about by the addition of nickel to 10 per cent aluminum bronze is that it increases the density of the alloy, and it is thereby all the more able to withstand hydraulic pressure. This is accordingly a field where these alloys could be ultilized to advantage.

A further advantage obtained by the use of nickel in aluminum bronze is that the resistance of the alloy to corrosion by sea water is increased.

The best alloy recommended for aluminum bronzes containing nickel is nickel 5 to 7 per cent, aluminum 10 per cent, remainder copper.

(c) *Effects of the Addition of Manganese*

Additions of small amounts of manganese to aluminum bronze improve the mechanical properties, in that the yield point and tensile strength are raised without any marked reduction in ductility. This is illustrated by the following figures taken from the 8th and 9th reports to the Institute of Mechanical Engineers:

Cu.	Al.	Mn.	Tensile Strength	Yield Point	Elongation
90.1	9.9	...	36.9 tons per sq. in.	12.4 tons per sq. in.	31
89.1	10.0	0.9	39.9 tons per sq. in.	16.0 tons per sq. in.	25

It will be seen from the above that the addition of 1 per cent of manganese raises the yield point by nearly 4 tons per square inch which makes these alloys the equal of the better known aluminum bronzes containing iron.

The addition of manganese to aluminum bronze in no way affects its resistance to corrosion, while on the other hand, it is a useful addition to make when the alloy is to be subjected to abrasion.

2. *The Use of Chill Castings*

The chief improvement in aluminum bronze to be obtained from the use of chill or die castings instead of sand castings is best illustrated by the following description of what happens in a sand casting.

It has been shown by A. B. Wilson[2] and others that 10 per cent aluminum bronze is subject to "self annealing" when allowed to cool slowly, as when cast in sand. This property of self annealing is brought about by the decomposition of the beta phase of the alloy on slow cooling into the two stable phases alpha and delta. The alpha phase is soft and ductile, while the delta phase is extremely hard and brittle. Moreover, on the decomposition of the beta phase into alpha and delta these latter phases exist in the lamellar form, resembling pearlite in steel, and the slower the cooling the coarser is this structure, with the result that the planes of hard delta provide planes of excessive weakness, along which fracture will readily take place when a casting containing it is subject to vibratory stresses.

There are three ways of preventing "self annealing," and they are:

(a) By removing the casting from the mold as soon as it has solidified, and allowing it to cool in the air.

(b) By the addition of 2 or 3 per cent iron, and

(c) By the use of chill casting.

It has been suggested that "self annealing" can be avoided by lowering the aluminum content to 8 per cent. While this may be true, it is not to be recommended since the reduction of aluminum content is accompanied by a corresponding reduction in mechanical properties, but the methods given above result in improved properties in addition to the avoidance of "self annealing."

The exclusive use of chill castings is the best method of the three given above, since some further advantages such as increased mechanical strength, a better surface appearance, and often increased soundness. Also casting the alloy in chill molds lessens the effects of dross which are encountered in sand casting. Cast-

[2] The Foundry, Oct. 1, 1920, p. 776.

ing in chill prevents "self annealing" because the casting is cooled too rapidly to allow of the decomposition of the beta phase into the alpha plus delta, thereby keeping the brittle delta in solution.

The following figures taken from the work of Carpenter and Edwards illustrate the improved properties that are obtained by the use of chill casting:

	Sand Cast	Chill Cast
Yield point	11.3 tons per sq. in.	12.4 tons per sq. in.
Tensile strength	31.70 tons per sq. in.	36.93 tons per sq. in.
Elongation on 2 in.....	21.7 per cent	30.5 per cent

3. *Casting and Mold Temperatures*

It is well known that the question of casting temperature is of the utmost importance when casting some of the non-ferrous alloys, as for example, phosphor bronze, the properties of which can be seriously diminished by the use of an incorrect casting temperature. This, however, is not found to be the case, within reasonable limits, for aluminum bronze, there being a fairly wide range of casting and mold temperatures that can be used without varying markedly the properties.

The most suitable casting and mold temperatures to be used should be found by trial and error for each particular alloy and mold. It will be found that, although slight, superior properties will be obtained by the use of the lowest casting temperatures at which it is possible to obtain a completely formed casting. Also, it will be found that sounder ingots are obtained by the use of lower mold temperatures since the chilling effect is greater.

4. *Mold Designs and the Position of the Casting in the Mold*

The question of mold design is one of extreme importance when the aluminum bronze alloys are die cast, and the importance is such that the success or otherwise of the process depends on the design of the mold for the particular job, and since this is a very specialized branch the writer is unable to offer much advice on that topic. He would, however, like to draw attention to the improvements, particularly as regards surface appearance, and this is all important in die casting, that can be obtained from so designing the mold that the casting is prepared in a horizontal posi-

tion. This results in an improved surface since splashing is avoided when pouring, as the metal enters the mold in a somewhat similar way to bottom pouring and causes no splashing through impinging on cores or against the sides.

Also, it will be found that a better surface condition is obtained by the use of the larger feeder heads, which also assist in producing sounder castings.

The question of mold design is further dealt with in the following section.

5. *Position of Feeder Heads*

In commercial practice, it is the custom to place the feeder head on a casting at a place where the casting is of narrow cross sectional area. This is done to facilitate the removal of the feeder head, but yet while this may be good practice from an economical standpoint, it is bad practice in other ways. For example, the thin sections of a casting will be the first to solidify, and the remaining still liquid thicker sections will, on solidification, contract and cause the formation of internal cavities, since they are cut off from the supply of still molten metal in the feeder head by this solidification of the thin section of the casting immediately under the feeder.

The above description shows that in the design of molds it should be so arranged that the feeder head is attached at a thick portion of the casting and that the thin portions of the casting are the first to be formed. When this is done it will be found that the thin section is fed by the supply of molten metal in the thicker portion above, and this in turn fed direct from the supply in the feeder head, thereby resulting in the production of much sounder castings.

6. *Heat Treatment*

One of the chief points in favor of aluminum bronze compared with other copper-rich non-ferrous alloys is that it is very susceptible to the influence of heat treatment, and the mechanical properties of the alloy can be very widely varied by it. For instance, the properties can be so varied as to give high tensile strength with a low ductility, a high ductility with low tensile strength, or many happy mediums.

Experimental work on the heat treatment of aluminum bronze has been carried out by Corse and Comstock[3] and by Grard[4] and others. These workers show that by means of quenching from a high temperature followed by an annealing the maximum useful properties can be imparted to the alloy. The treatment recommended is quenching from 900 degrees Cent. (1652 degrees Fahr.) followed by an anneal at 675 to 700 degrees Cent. (1247 to 1292 degrees Fahr.). It has been found by the writer that this is the treatment that should be given to those castings which have "self-annealed," when the normal properties for the alloy will be restored to it.

From the above it is evident that the development work on aluminum bronze is progressing along correct technical lines, all of which means that the engineers will have available for their purposes and needs better known and more reliable alloys in the aluminum bronzes than ever before. Its well known uses as an anti corrosive material, as a strong structural bronze and as a material for parts to resist wear, such as worm gear wheels and certain types of bearings are already well known, and it is hoped that the information in this paper will help to round out the picture of the possibilities of this important material.

Discussion

Mr. Robbins: Does the addition of lead to the aluminum bronze affect it any?

C. J. Zaiser: It does not to my knowledge. You all know the treachery of aluminum bronze. I don't think there are two companies which use the same formula. For instance, we use no manganese; others do. We use electrolytic copper; others use none. I do not believe the lead would kill the elongation or the ductility. Once in a while we do get a little impurity in our metal. The lead, however, has a tendency to coat the outside surface of the casting dark. They do not have the bright color.

Mr. Robbins: What I wanted to know is what would be the possibility of hot working with two or three per cent lead in there? What effect would the addition of lead have?

Chairman N. K. B. Patch: I don't think there is anybody who makes a business of the hot working of aluminum bronze who uses a lead content

[3] Foundry, Jan., 1917, pp. 21-29.
[4] Grard, *Aluminum and Its Alloys*, Constablè, London, 1921.

deliberately. Of course, those hot worked pieces are not generally used for anti-friction purposes.

R. L. BINNEY: I would like to ask about the amounts of iron, manganese, or possibly nickel used to eliminate grain growth at elevated temperatures. Do you add an amount sufficient to inhibit grain growth when you get temperatures up around 1,500 or possibly higher? How do you maintain the hardness? What is the minimum of nickel you could put in there to help maintain its hardness?

MR. ZAISER: I would say 3 per cent would be the minimum amount of nickel. But I don't intend it for 1,500 degrees temperature. The melting point is about 1,800. In the research work we did we frequently went up to 900 degrees Fahrenheit. I don't want to be personal, but we ourselves have never added nickel to our own mixture. We have added iron. We have experimented having it as high as 65 per cent iron and have gotten quite a good structure. It was very hard, but a very short structure as well. When you speak of adding nickel you make the metal more dense. But I do not think it would be safe to go over 900 or 1,000 degrees Fahrenheit, because of the low melting point of this metal.

I don't believe that answers your question, but after all, if you can't use the metal there is no use making it.

I should like to call attention to the facilities of the Aluminum Bronze Manufacturers' Institute with headquarters in Washington. The director, W. M. Corse, is accumulating in his office technical information on aluminum bronze alloys, and these data are available to engineers who are interested in the correct properties of these alloys.

The Reduction of Molding Losses

By R. A. Greene,* Mansfield, O.

High foundry losses and especially molding losses are not always prevented by chemists, metallurgists, or engineers. Many of you know of foundries maintaining excellent laboratories and technical organizations whose loss and quality of product is entirely out of proportion to the technical effort that they are expending. However, the tendency of modern thinking is more and more toward the combining of theory and practice. Undoubtedly some of you know of instances where the foundry man thought that it was impossible to make gray iron castings unless he had a certain kind of pig iron, looking very skeptically upon the chemist's mixture from analysis. Many examples similar to this can be cited, the outcome of which shows very great benefits derived by combining theory and practice.

The real problem that we have now to consider is—what can be done to get closer union or co-operation between the molders, the instructors, the foremen, the chemists, the metallurgists, the engineers, or any other groups in any way connected with this line of activity, with the main idea in mind of producing quality castings with a low loss.

It is not our intention to attempt a complete answer to this all-important problem, but we have developed certain plans or schemes which in practice do materially contribute to its solution. While some of the ideas are not necessarily new, the manner in which we are applying them may be of interest to you.

One of the difficulties and perhaps the greatest difficulty in connection with this program was the problem of arousing the interest of the foundry workers in the theory of their problem that is available through the technical department. Molders, as a rule, are not noted as great seekers after scientific truth. It was hoped, therefore, to develop in them a bit of the engineer's spirit, inciting them to study the why and wherefore of their losses more carefully.

*Assistant Manufacturing Superintendent, Ohio Brass Co.

In seeking a solution to this problem, the baseball plan of organization was continually coming to mind. If the earnestness, the "head work," and the team work that prevails in a baseball team could be duplicated in a foundry, real results would be possible.

How are these things promoted in a ball team? We decided that they were the result of *accurate records, publicity,* and *friendly rivalry.* Upon these we decided to build our system.

Accurate Records—Nucleus of a System Already in Operation

For some time the molders at The Ohio Brass Company have been paid for the number of molds they make, less the castings that are dirty or shifted; hence, it is necessary to keep each molder's castings separate from the time they are made until they are passed by the inspector. To get an accurate record of all the bad castings, it only remained to elaborate this system somewhat and provide forms on which the inspector's findings could be recorded for display.

An accurate count of our production is obtained as follows. In the brass foundry each molder's floor is poured off about eight times a day. The castings, however, are not gathered as soon as they are shaken out, but are piled at the side of the molder's floor where they remain until the end of the day. At the end of the day's run, the castings are carefully counted by the instructor. The molder's count, which he keeps to check his pay, must agree with the instructor's count before the castings are moved. In the beginning, we had some difficulty in getting these to check, but after a few week's operation, the discrepancies practically disappeared.

In the brass casting department, which is the first stopping point, the cores and sprues are removed, the castings are sand blasted, rough ground, and sorted; castings from each pattern being put into suitable containers. Attached to each container is the original record showing the molder's clock number, the pattern number, and the number of castings as filled out in the beginning by the foundry production department and checked by the instructor.

The containers are now delivered to the inspector who divides the castings into good and bad, and the bad he further divides into dirt, shift, mis-run, core trouble, spoiled and short. Short shows that the good and bad together do not equal the total called for on the instructor's ticket.

Shortage was originally one of the big losses. This, however, was not realized until brought to light by our present manipulations. Shortage is caused by miscount, the error having slipped by in some manner, or it may be, and frequently is, caused by spoiled castings—that is, castings spoiled where they are cut from the sprues, and which the sprue cutter has failed to turn in. This sprue cutter man, when he spoiled a casting in this manner, would invariably throw the spoiled casting into the scrap, partly because he thought it was useless to put it in with the good castings and partly to hide his carelessness.

When several things of this nature had happened, the importance of having the various items checked was obvious. I do not want to infer, however, that an absolute banker's count is necessary, but a check that would give some predetermined degree of accuracy is desirable rather than to leave it to the judgment of the worker. For instance, in weight counting, the scales were checked occasionally by actual count and the percentage variation was noted and recorded or remembered.

Another reason for careful checking—one time we had a pattern which seemed very difficult to run by the majority of the molders. We thought that this pattern was wrong and should be changed. We hesitated, however, because there was one molder who seemed to be very successful with the pattern as it was. This went on for some time, but finally, by accident, this man was caught in the act of secretly disposing of the defective castings that would be deducted from his pay. This he did before the castings left his floor. At the time, to avoid the trouble of counting the castings, the inspector would simply deduct the bad castings from the original count. The difference was the good castings for which the molder was paid. This example went a long way in helping to get things systematized.

Of course, everyone dislikes the trouble, bother, and expense

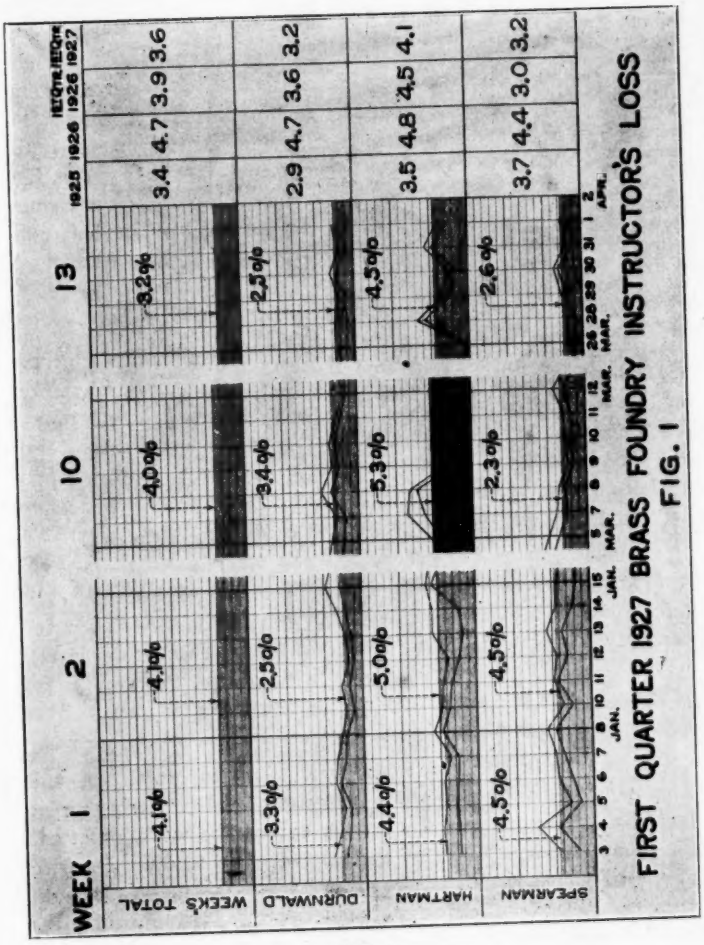

WEEK 1 2 10 13
1925 1926 1926 1927
WEEK'S TOTAL
DURNWALD
HARTMAN
SPEARMAN
4.1% 4.1% 4.0% 3.2% 3.4 4.7 3.9 3.6
3.3% 2.5% 3.4% 2.5% 2.9 4.7 3.6 3.2
4.4% 5.0% 5.3% 4.5% 3.5 4.8 4.5 4.1
4.5% 4.5% 2.3% 2.6% 3.7 4.4 3.0 3.2
3 4 5 6 7 8 9 10 11 12 13 14 15 JAN.
5 7 8 9 10 11 12 MAR.
25 26 28 29 30 31 1 2 MAR. APR.
FIRST QUARTER 1927 BRASS FOUNDRY INSTRUCTOR'S LOSS
FIG. 1

FIG. 1

incurred in installing and operating any kind of system, although they all agree or half agree that it is necessary. Stopping a few molders from doing things like this molder was doing would justify and more than pay for an accurate count.

It has been my experience that as soon as a worker discovers that his efforts are not accurately recorded, and he is quick to sense this, he relaxes his effort, takes less and less pains, until finally the quality of his production is below what is desired. He tries to use good judgment, but, as a rule, unless he is a mechanic with an intelligence above his present position, his judgment as to just what to slight and what not to slight is often erroneous.

Publicity—Creating Interest—Attracting Attention

The inspector now turns in to the inspection department's clerk his findings, which the clerk posts on the sheets, as shown in Fig. 3. There is one of these sheets for each instructor's group for each day. It not only shows each molder's record, but also the group's or the instructor's record for the day. Care is taken to keep the same rotation of the molder's numbers, so that by putting the sheets together a molder's record can be easily seen and studied over any period.

The sheets are so arranged on the bulletin board that each molder's total loss, molding loss, and foundry loss is shown for each day of the week. That is, first Monday's sheet is displayed; when Tuesday's sheet is displayed it is put on top and covers Monday's with the exception of the last three columns. This arrangement is shown in Fig. 2.

When these sheets are displayed, the daily total loss and daily molding loss of each group is plotted on the quarterly graphic record as shown in Fig. 1. At the end of the week, or at the time that Monday's sheet of the next week is ready, the record of the combined loss of all the groups as well as the loss of each group is blocked in, either with blue or red. At this time, the finished week's daily sheets are removed and the new week started.

The records, the forms, and the charts were arranged with the idea of attracting attention. Blue and red figures were used, blue for loss less than 5 per cent, and red for a loss above 5

BRASS FOUNDRY-DAILY LOSS

INSTRUCTOR HARTMAN FOR MARCH 18

MOULDER	PATTERN	MADE	GOOD	BAD	MOULDING SHIFT	MOULDING SHIFT	FOUNDRY N.R.	FOUNDRY DIRECT	FOUNDRY C.S.	FOUNDRY SHIFT	SATURDAY MADE	SATURDAY TOTALS BAD	SATURDAY TOTALS MOULD	SATURDAY TOTALS DRY.	FRIDAY TOTALS BAD	FRIDAY TOTALS MOULD	FRIDAY TOTALS DRY.	THURSDAY TOTALS BAD	THURSDAY TOTALS MOULD	THURSDAY TOTALS DRY.	WEDNESDAY TOTALS BAD	WEDNESDAY TOTALS MOULD	WEDNESDAY TOTALS DRY.	TUESDAY TOTALS BAD	TUESDAY TOTALS MOULD	TUESDAY TOTALS DRY.	MONDAY TOTALS BAD	MONDAY TOTALS MOULD	MONDAY TOTALS DRY.
1103	12443	656	617	65	6	63						10,0	10,0	0,0	1,9	1,9	0,0	0,3	0,2	0,05	1,0	0,7	0,3	0,8	0,4	0,4	1,3	0,3	1,0
											686	69	69		24	26		5	2	1	15	10	5	11	5	6	20	5	15
1108	1650	164	156	8	8							4,9	4,9	0,0	3,0	2,6	0,4	16,9	16,6	0,3				0,0	8,6	8,6	0,0	21,8	21,2	0,6
											164	8	8		29	25	4	133	131	2	49	49		33	33		85	83	2
1112	14067	216	192	24			23		1			11,1	0 0	11,1	4,2	2,2	2,0	5,0	2,3	2,7	6,1	0,0	6,1	10,0	1,8	8,2	9,5	0,5	9,0
											216	24		24	44	23	21	43	20	23	27		27	40	7	33	39	2	37
1150	14474	980	958	22	3	15	4					2,2	1,8	0,4	8,4	8,3	0,09	5,3	5,3	0,0	3,0	1,2	0,8	0,3	4,1	4,5	6,7	6,7	0,0
											980	22	18	4	91	90	1	2	2		5	3	2	2	1	1	4	4	
1158	14494	41	33	8	4		4					19,6	9,8	9,8	8,8	3,8	5,0	2,2	5,6	6,6	2,6	1,3	2,2	4,3	1,4	2,9	3,5	2,8	0,7
											41	8	4	4	7	3	4	11	5	6	40	2	38	9	3	6	15	12	3
1164	14457	104	103	1			1					1,1	0,7	0,4	5,3	5,0	0,3	2,9	2,9	0,0	1,3	1,1	0,2	9,6	9,1	0,5	7,5	5,3	2,2
	14581	170	168	2	1				1		274	3	2	1	57	54	3	41	41		17	14	3	93	88	5	85	60	25
TOTALS	NUMBER	5227	4997	230	80	79	47		4		5227	230	89	71	435	369	86	667	564	103	320	222	98	762	688	74	734	549	185
	PERCENT				1,5	1,5	1,3		0,1			4,3	3,0	1,3	3,4	2,7	0,7	5,0	4,2	0,8	3,2	2,2	1,0	8,2	7,4	0,8	8,3	6,2	2,1

FIG. 2

FIG. 2

BRASS FOUNDRY—DAILY LOSS

Instructor Hartman for March 12 192 Saturday

Machine	Pattern	Made	Good	Bad	MOLDING Cint	MOLDING Stem	FOUNDRY W. R.	FOUNDRY Core	FOUNDRY B.O.T.	Short	TOTALS Made	TOTALS Bad	TOTALS Molding	TOTALS Foundry
1103	14449	686	617	69	6	63					10.0	10.0	0.0	
											686	69	69	—
1108	1630	164	156	8	8						4.9	4.9	0.0	
											164	8	8	—
1112	14047	216	192	24			23		1		11.1	0.0	11.1	
											216	24	—	24
1150	14474	980	958	22	3	15	4				2.2	1.8	0.4	
											980	22	18	4
1158	14454	41	33	8	4		4				19.6	9.8	9.8	
											41	8	4	4
1164	14457	104	103	1		1					1.1	0.7	0.4	
	14551	170	168	2	1				1		274	3	2	1
Totals	Number	5227	4997	230	80	79	67	4			5227	230	159	71
	Percent				1.5	1.5	1.3	0.1				4.3	3.0	1.3

FIG. 3

per cent. The bulletin board was a rather elaborate affair—made so purposely. Heads and men of other departments were asked to give the posted records at least a cursory glance as often as possible. We tried to imitate the baseball score—the more spectators the greater the enthusiasm—the greater the enthusiasm the keener the competition.

Other things of a more personal nature were resorted to. When the supervisor of this work posted the daily sheets, he endeavored to get the instructors to gather around the bulletin board to view their latest record. This, however, required no effort. Not only the instructors, but also the molders, whenever it was possible for them to do so, were anxious to see their records. The interest shown by the molder was encouraging because any time lost by him in looking at the exhibit means money loss unless he can profit by what is there shown, and as they continue this practice, it proves that they must get some benefit.

The supervisor's opportunity at this time to hear about the instructor's troubles is obvious. Many statements and criticisms are made and arguments are started that can readily be used to advantage by a supervisor, who is trying to reduce the loss.

For instance, the supervisor will make some remark to the instructor about one of his molders who has been running a certain pattern with what looks like an excessive loss. The instructor will admit that the loss is excessive, that he has tried several things without success, that the foreman has made some suggestions that have been tried but were not successful, and the loss still continues. The supervisor looks at the job, thinks about it, talks about it, brings it to the attention of the foundry superintendent, to the metallurgists, to the chemists, and in many cases to the manufacturing superintendent—the main idea being to get as much attention as possible focused on any job running with a loss higher than the average.

A molder is running with an excessive loss, the cause of which, upon investigation, is found to be defective cores. When the instructor's attention is called to this, his excuse is that the cores are supposed to be inspected by the core department and come to him perfect. He is told that while his remarks may be

so, nevertheless, that does not entirely relieve him of the responsibility. A mere glance at the box should tell a man of his experiance whether they looked good or bad, and if they looked bad he should further investigate. He is also told that he should teach his molder something about good and bad cores. Now some one of the instructors will think about remarks such as this and will make a reduction in his loss. This reduction is pointed out to him and commented upon. It will also be noted by the other instructors who, through the exhibit, are eagerly seeking just such things as this. They study the exhibits to see how and where another instructor reduces his loss.

Another good illustration is the spoiled casting loss. This loss is made in removing the sprues, either by the sprue cutter or by the grinder, and formerly was not shown on the instructor's sheet. This loss, however, helped to increase the scrap, and it was thought that if the help of the instructor could be enlisted another source to attract attention would be brought to bear on the men who were responsible for this loss. It also made another division in the record over which, with proper handling, competition could be aroused between the instructors. Another chart was designed for the sprue cutters. On this chart was recorded daily the castings spoiled in removing the sprues. This procedure reduced the spoiled casting loss from about 1300 castings to less than one hundred a week.

Shortage was another division of the loss to which very little attention had been paid. Shortage was caused by carelessness in counting. In weight counting it was caused by not having the scales checked occasionally. The castings spoiled by the sprue cutter would be thrown in the scrap, either as mentioned before, because he thought that it was not necessary to put them in with good castings, or else to hide his carelessness. The help of the instructor was enlisted in this similar to the way his help was enlisted in the spoiled casting division.

To enlist the interest of the instructor in all this work not only was his sportsmanship aroused by the display of his records, but he was put on a bonus. This bonus was so arranged that it did not function unless the weekly group loss was below ten per

cent. It was thought that this plan would be an incentive, although it has not come up to expectations. Some of the instructors have asked to have the bonus taken off, preferring to be on a weekly salary. This was granted in several cases, with a result that was even better than the bonus scheme, which tends to prove that the greatest spur is, after all, pride in achievement.

Friendly Rivalry—Competition

The third idea, that of inciting rivalry or competition, was perhaps the major idea in mind in the design or arrangement of the whole system. It was thought that if competition in reducing loss could be aroused between the molders and between the instructors, and also if a molder or an instructor or the foundry as a whole could be incited to strive to excel previous records, commendable results could be accomplished.

If an instructor has a molder who is having trouble with dirty or misrun castings, he, of course, consults his foreman, but he is encouraged to seek information from the technical department too. We feel that the more theory that we can get mixed up with practice the better results we eventually achieve.

In order to encourage this close relation with the technical department we have taken groups of instructors and molders into our laboratory and have discussed with them the methods used in controlling the metal, the cores, and the sand. The pyrometers were explained to them. They were shown how to measure the bond, the permeability, and the moisture content of molding sand. The relation of these properties to casting losses was discussed. This has helped the instructors and molders to understand their problems better and has also resulted in better co-operation.

Now, the results of this arrangement are very commendable. We started this scheme in the latter part of 1923. The loss for this and previous years was around 8½ per cent, which represented approximately 400,000 pounds of bad castings. For the years of 1924, 1925 and 1926 the loss has averaged between 4 and 4½ per cent, making a saving of approximately 200,000 pounds of castings a year for the last three years.

Discussion

C. J. Zaiser: Mr. Greene, may I ask how many molders you employ in your brass division?

R. A. Greene: About 40. It has been as high as 50. We have about 15 men to a gang. Eighteen is supposed to be the limit. In the malleable section it will sometimes run as high as 20. We try to hold it down to 18 men.

Member: How does your instructor function?

R. A. Greene: The instructor looks after the molders in his gang the same as a foreman. When a new molder starts, his instructor tells him about the policy of the company, what he is to do, the peculiarities of certain patterns, and what he is to look out for. It is the instructor's job to see that the man understands and follows instructions.

Member: Does each instructor have the same molders under him all the time? Do certain molders have a simpler work than others?

R. A. Greene: The instructor has the same molders under him all the time. Different molders have different lines of work. For example, in making valves we have body men, and trimming men; trimming, signifying all parts of a valve except the bodies. Yes, some molders have simpler work than others. We make no effort to have each instructor have the same kind of work. We compare one instructor with another only as to progress. For example, if instructor A operates with an average loss of 3 per cent on his line of work while instructor B's average loss on his line, which is not similar, is six per cent we consider instructor A the better. Instructor B was picked because he was supposed to know the line of work for which he was picked.

The daily sheets with the exception of percentage figures are made by the brass casting inspector's clerk. Seventy-five per cent of the figures on these sheets are used for payroll purposes. The percentage figures are calculated by the manufacturing superintendent's stenographer, and the sheets are then posted on the bulletin board in the foundry by the supervisor of this work. At this time the losses are plotted on the quarterly chart shown in Fig. 1.

Mr. Cheatham: How many days late are the reports?

R. A. Greene: About two days.

Mr. Cheatham: Do you segregate the castings after they are inspected?

R. A. Greene: No. A container is provided for each pattern number . The castings are sorted after they come from the sand blast and put into their respective containers before they go to the inspectors.

R. R. Clarke: Do you discount your molders for defective castings both in time and credit?

R. A. Greene: The molders are paid for the number of molds they make. If a mold is from a pattern, which is a gate of twelve, and there are six misrun castings the molder is not paid for the mold. On the other hand

if but five castings are misrun from this gate of twelve the molder is paid for the full mold.

R. R. CLARKE: To what extent do you hold your molders responsible?

R. A. GREENE: All castings turned back by the inspector for dirt or shift are deducted from the molder's pay. Castings turned back for misrun, core trouble, spoiled in removing sprues or any special defects are not deducted from the molders' pay.

R. R. CLARKE: Supposing you had extremely hard cores, or a core in which the vent did not show up at all. Would you hold the molder responsible?

R. R. GREENE: No, not as regular practice. However, if the molder uses a core that is bad and so bad that he should have seen it, sometimes the loss so caused is deducted.

R. R. CLARKE: Supposing you have a pattern that hasn't been shifting, but develops a shift for some unknown reason. No one knows that until after the castings have been made. What do you do in that case?

R. A. GREENE: Standard practice is to deduct shifted castings from the molder's pay, and it is usually so done. This rule may be waived for exceptional cases if the instructor so desires. With our method of operating, the molder could not make more than about ten molds before the shift would be discovered.

R. R. CLARKE: Do you require your molders to look at the castings when they are shaken out?

R. A. GREENE: No. The instructor carefully looks at the castings when they are shaken out. If a pattern which has previously given trouble, or if a new pattern is put in the sand for the first time, the instructor arranges to have a few molds made before going into active production.

R. R. CLARKE: I think the more you can increase the responsibility of a molder the more sure you are of getting him down to a basis where you want him. As long as you give him a loophole of escape or a chance for an alibi, or some excuse whereby he can blame the castings on some one else, you haven't got him pinned down to a basis where he will do his level best. I believe, where you can make the molders the accountable agent, whether it is in the core room or wherever it is, that that has been a greater asset than all the rest. As long as you give him a chance to get by with the excuse that, "It isn't my fault," you are giving him something that will take away from him his accountability and responsibility.

R. A. GREENE: You are absolutely right. There was a time when we divided the dirty castings into dirt and slag. The dirt we deducted from the molder's pay, but the slag we said was in the metal and the molder was not responsible.

We thought with this arrangement that the dirty casting loss would be cut in two. The dirty castings, however, staid about the same and we had just about that much more slag. For example, the dirty casting loss when the dirt and slag was combined was, say, about 4 per cent. When they were divided we had dirt 4 per cent and slag about 3.5 per cent. As soon

as we recombined them and made the molder responsible the combined loss fell to about 4.5 per cent.

MR. CHEATHAM: I would like to know if your molders are responsible for the pouring of the metal?

R. A. GREENE: No. Not in our Brass Foundry.

MR. CHEATHAM: Doesn't he pour his own metal?

R. A. GREENE: Yes.

MR. CHEATHAM: Well, why isn't he responsible for pouring the mold when the metal for instance, is too cold?

R. A. GREENE: The metal is in charge of the metal crew, which governs the temperature by the pyrometer and is carried to the molder's floor by the metal crew. The molder or the instructor supervises the actual pouring of the metal into the molds, and may challenge the temperature if they think it not right, but as the temperature is predetermined by the technical department, and engineered by them, the molder does not have much say. This is one reason why the misrun castings are not deducted from the molder's pay.

MR. CHEATHAM: Do you penalize your molders for the cores they lose in the castings?

R. A. GREENE: No.

CHAIRMAN N. K. B. PATCH: Mr. Greene, you spoke of the rivalry between the instructors as being that of a baseball nine. Is there any prize or anything of that sort at the end of the year for the instructor who wins out as the star among the bunch?

R. A. GREENE: No.

CHAIRMAN N. K. B. PATCH: These instructors who have charge of 18 or 20 men, I thought it might be some incentive to them if you had something in the way of a bonus or a prize that they would receive if they were at the top, or second, or third, just as they have for the baseball team which is at the top.

R. H. GREENE: Yes, I have thought and schemed and am still scheming on this idea but so far I have not hit on any plan that is acceptable to our management.

H. M. ST. JOHN: In a case where the molders don't pour their own castings, would you still consider it practicable to use a somewhat modified system of this sort? That gives them another beautiful excuse.

R. A. GREENE: Yes. Our "Brass Castings Spoiled" is an example. These are castings spoiled by the sprue man in removing the gates and sprues. Formerly, when a casting was spoiled in this manner it was thrown in the scrap and no account taken of it. To make the castings "made" balance with the "Good" and "Bad" this practice had to be stopped. When we did stop it, it was found the "Brass Castings Spoiled" was a very considerable item. As a means to attract attention, and to get all the help possible we not only made a special report for the sprue cutter crew but we also posted it as a part of the molder's loss. While we do not penalize the molder for this loss it is added to the loss of the group for the reduc-

tion of which (the group loss) we paid the instructor a bonus. This caused considerable discussion and argument on the part of the instructor, who, of course, claimed that he had no say or jurisdiction over the sprue cutter group. Our answer was that what the instructor said was right but we were simply dividing between him and the company any saving that the sprue cutter group could make in reducing this loss. Therefore, he (the instructor), could not say very much against the adding of the loss to his group and if he *could do anything to lower the loss he would be benefited.* This helped. We enlisted the instructor's good will in helping to reduce the "Brass Castings Spoiled." Our idea in doing this was to get the instructor not only interested in his own job but interested in the running of the foundry as a whole.

H. M. St. John: But you will charge the pouring of the castings against the molder?

R. A. Greene: We charge it against but do not penalize the molder. I mean by this, that dirty, shifted, misrun, core trouble, or brass castings spoiled, are all charged against the molder and show up and are posted on the sheets as his daily loss. We do not, however, deduct from his pay any lost castings except those caused by dirt or shift. If you will look at Fig. 2 you will see two columns (dirt and shift), marked "Molding" and several columns marked "Foundry." Molder 1112 on Saturday made 216 castings from Pattern 14047. He lost 24. The 24 castings, however, were lost from defects in the "Foundry Columns" and while the molder was not penalized for this loss, he, nevertheless, received a red mark. These red marks cause nearly as much commotion as a deduction. Both the molder and the instructor will make much fuss over the red marks.

Member: What authority does your instructor have? Does he have the authority to discharge a man?

R. A. Greene: When a molder is not satisfactory to an instructor the instructor does not have to keep him. The molder is either transferred to another group, to some other department, or discharged.

Mr. Wishart: Do you promote your instructors from the regular corps of molders?

R. A. Greene: As a rule, yes. On one or two occasions we have hired outside men.

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